MARCH 1987 VOL. 5 NO. 3 $3.95

FOR THE IBM SYSTEMS PROFESSIONAL

PC TECH JOURNAL®

DESKPRO 386

Compaq's Powerful Entry in the 80386 Sweepstakes

COMPATIBILITY/PERFORMANCE UPDATE

MODULA-2 ROUNDUP

03 71486 02166 7

NEW

Eureka: The Solver™

Anyone and everyone who routinely works with equations needs Eureka: The Solver

It solves the most complex equations in seconds. Whether you're a scientist, engineer, financial analyst, student, teacher, or some other professional, you need Eureka: The Solver!

Any problem that can be expressed as a linear or non-linear equation can be solved with Eureka. Algebra, Trigonometry and Calculus problems are a snap.

Eureka: The Solver also handles maximization and minimization problems, does plot functions, generates reports, and saves you an incredible amount of time.

X+exp(X) = 10 solved instantly instead of eventually!

Imagine you have to "solve for X," where X + exp(X) = 10, and you don't have Eureka: The Solver. What you do have is a problem, because it's going to take a lot of time guessing at "X." Maybe your guesses get closer and closer to the right answer, but it's also getting closer and closer to midnight and you're doing it the hard way.

With Eureka: The Solver, there's no guessing, no dancing in the dark—you get the right answer, right now. (PS: X = 2.0705799, and Eureka solved that one in .4 of a second!)

How to use Eureka: The Solver

It's easy.

1. *Enter your equation into the full-screen editor*
2. *Select the "Solve" command*
3. *Look at the answer*
4. *You're done*

You can then tell Eureka to

- *Evaluate your solution*
- *Plot a graph*
- *Generate a report, then send the output to your printer, disk file or screen*
- *Or all of the above*

Eureka: The Solver includes

- ☑ *A full-screen editor*
- ☑ *Pull-down menus*
- ☑ *Context-sensitive Help*
- ☑ *On-screen calculator*
- ☑ *Automatic 8087 math co-processor chip support*
- ☑ *Powerful financial functions*
- ☑ *Built-in and user-defined math and financial functions*
- ☑ *Ability to generate reports complete with plots and lists*
- ☑ *Polynomial finder*
- ☑ *Inequality solutions*

*Introductory price—good through July 1, 1987

Some of Eureka's key features

You can key in:

- ☑ *A formula or formulas*
- ☑ *A series of equations—and solve for all variables*
- ☑ *Constraints (like X has to be < or = 2)*
- ☑ *A function to plot*
- ☑ *Unit conversions*
- ☑ *Maximization and minimization problems*
- ☑ *Interest Rate/Present Value calculations*
- ☑ *Variables we call "What happens?," like "What happens if I change this variable to 21 and that variable to 27?"*

All this power for only $99.95!

Equation-solving used to be a mainframe problem, but we've solved that problem.

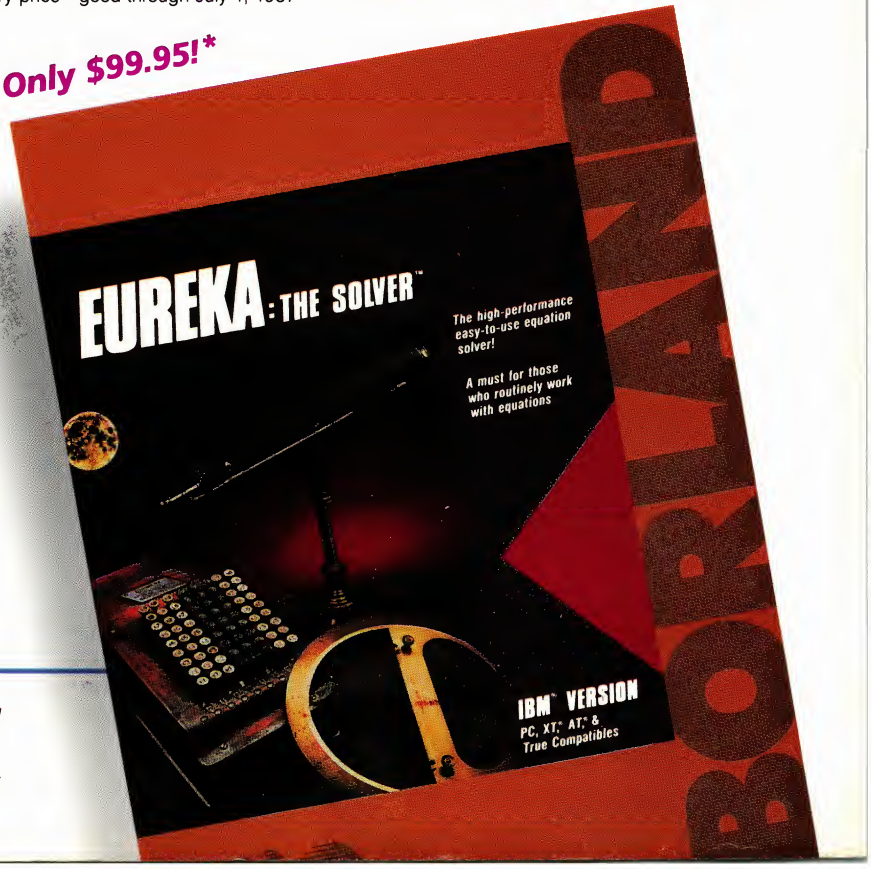
Eureka: The Solver is all you need—and it's yours for only $99.95!

That kind of savings you can calculate with your fingers!

System requirements

IBM PC, AT, XT, Portable, 3270 or true compatibles. PC-DOS (MS-DOS) 2.0 and later. 384K.

Only $99.95!*



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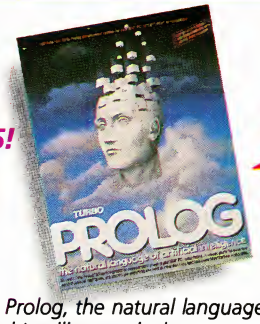
BI-1103

Turbo Prolog™

> *"If you're at all interested in artificial intelligence, databases, expert systems, or new ways of thinking about programming, by all means plunk down your $100 and buy a copy of Turbo Prolog."*
> **Bruce Webster, BYTE**

Only $99.95!



Turbo Prolog, the natural language of Artificial Intelligence, is the most popular AI package in the world with more than 100,000 users. It's the 5th-generation computer programming language that brings supercomputer power to your IBM PC and compatibles. You can join the AI revolution with Turbo Prolog for only $99.95. Step-by-step tutorials, demo programs and source code included.

New! Turbo Prolog Toolbox

NEW

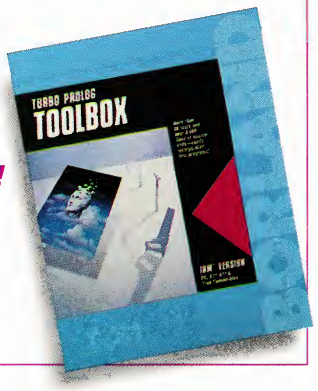
Our new Turbo Prolog Toolbox™ enhances Turbo Prolog—with more than 80 tools and over 8,000 lines of source code that can easily be incorporated into your programs. It includes about 40 example programs that show you how to use and incorporate your new tools.

New Turbo Prolog Toolbox features include:

- ☑ *Business graphic generation*
- ☑ *Complete communications package*
- ☑ *File transfers from Reflex, dBASE III, 1-2-3, Symphony*
- ☑ *A unique parser generator*
- ☑ *Sophisticated user-interface design tools*

It's the complete developer's toolbox and a major addition to Turbo Prolog. You get a wide variety of menus—pull-down, pop-up, line, tree and box—so you can choose the one that suits your application best. You'll quickly and easily learn how to produce graphics; set up communications with remote devices; read information from Reflex,® dBASE III,® Lotus 1-2-3® and Symphony® files; generate parsers and design user interfaces. All of this for only $99.95.

Only $99.95!



System requirements

Turbo Prolog: IBM PC, XT, AT or true compatibles. PC-DOS (MS-DOS) 2.0 or later. 384K. Turbo Prolog Toolbox requires Turbo Prolog 1.10 or higher. Dual-floppy disk drive or hard disk. 512K.

Turbo Pascal®

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The power and high performance of Turbo Pascal is already in the hands of more than half-a-million people. The technically superior Turbo Pascal is the de facto worldwide standard and the clear leader.

The Turbo Pascal family includes:

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- *Turbo Editor Toolbox®*
- *Turbo Graphix Toolbox®*
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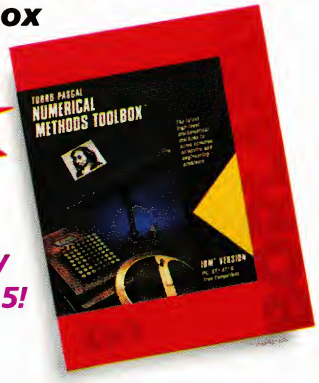
- *Turbo Pascal Numerical Methods Toolbox™*

Turbo Pascal, the worldwide standard in high-speed compilers, and family.

> *"The language deal of the century."*
> **Jeff Duntemann, PC Magazine**

New! Turbo Pascal Numerical Methods Toolbox

NEW



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What our new Numerical Methods Toolbox will do for you now:

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As well as a free demo FFT program, you also get Least Squares Fit in 5 different forms:

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They're all ready to compile and run.

All this for only $99.95!

System requirements

IBM PC, XT, AT or true compatibles. PC-DOS (MS-DOS) 2.0 or later. Turbo Pascal 2.0 or later. Graphics module requires graphics monitor with IBM CGA, IBM EGA, or Hercules compatible adapter card, and requires Turbo Graphix Toolbox. 8087 or 80287 numeric co-processor not required, but recommended for optimal performance. 256K.

Turbo Pascal 3.0.
Includes 8087 & BCD features for 16-bit MS-DOS and CP/M-86 systems. CP/M-80 version minimum memory: 48K; 8087 and BCD features not available. 128K.

NEW

Turbo Basic®

Introducing Turbo Basic, the high-speed BASIC you'd expect from Borland!

It's the BASIC compiler you've been waiting for. And it's so fast that you'll never have to wait again.

Turbo Basic is a complete development environment; it includes a lightning-fast compiler, an interactive editor, and a trace debugging system.

Because Turbo Basic is compatible with BASICA, chances are that you already know how to use Turbo Basic.

With Turbo Basic your only speed is "Full Speed Ahead"!

You probably already know us for both Turbo Pascal® and Turbo Prolog.™ Well, we've done it again!

We created Turbo Basic, because BASIC doesn't have to be slow.

In fact, building fast compilers is a Borland specialty; both our Turbo Pascal and our Turbo Prolog outperform all their rivals by factors, and with Turbo Basic, we're proud to introduce the first high-speed BASIC compiler for the IBM®PC. If BASIC taught you how to walk, Turbo Basic will teach you how to run!

The Critics' Choice

"Borland has succeeded in stretching the language without weighing us down with unnecessary details . . . Turbo Basic is the answer to my wish for a simple yet blindingly fast recreational utility language . . . The one language you can't forget how to use, Turbo Basic is a computer language for the missus, the masters, the masses, and me.

Steve Gibson, InfoWorld

Borland's Turbo Basic has advantages over the Microsoft product, including support of the high-speed 8087 math chip.

John C. Dvorak"

Turbo Basic ends the basic confusion

There's now one standard: Turbo Basic.

It's fast, BASICA-compatible, and because Turbo Basic is a Borland product, the price is right, the quality is there, and the power is at your fingertips. You see, Turbo Basic's part of the fast-growing Borland family of programming languages—we call it the "Turbo Family." Hundreds of thousands of users are already using Borland's languages, so you can't go wrong. So join a whole new generation of smart IBM PC users—get your copy of Turbo Basic today. You get an easy-to-read 300+ page manual, two disks, and a free MicroCalc spreadsheet—and an instant start in the fast new world of Turbo Basic. All of this for only $99.95—Order your copy of Turbo Basic today!

Free spreadsheet included, complete with source code!

Yes, we've included MicroCalc, our sample spreadsheet, complete with source code, so that you can get started right away with a "real program." You can compile and run it "as is," or modify it.

A technical look at Turbo Basic

- ☑ *Full recursion supported*
- ☑ *Standard IEEE floating-point format*
- ☑ *Floating-point support, with full 8087 (math co-processor) integration. Software emulation if no 8087 present*
- ☑ *Program size limited only by available memory (no 64K limitation)*
- ☑ *EGA and CGA support*
- ☑ *Access to local, static, and global variables*
- ☑ *Full integration of the compiler, editor, and executable program, with separate windows for editing, messages, tracing, and execution*
- ☑ *Compile, run-time, and I/O errors place you in the source code where error occurred*
- ☑ *New long integer (32-bit) data type*
- ☑ *Full 80-bit precision*
- ☑ *Pull-down menus*
- ☑ *Full window management*

System requirements

IBM PC, XT, AT and true compatibles, PC-DOS (MS-DOS) 2.0 or later. One floppy drive, 256K.

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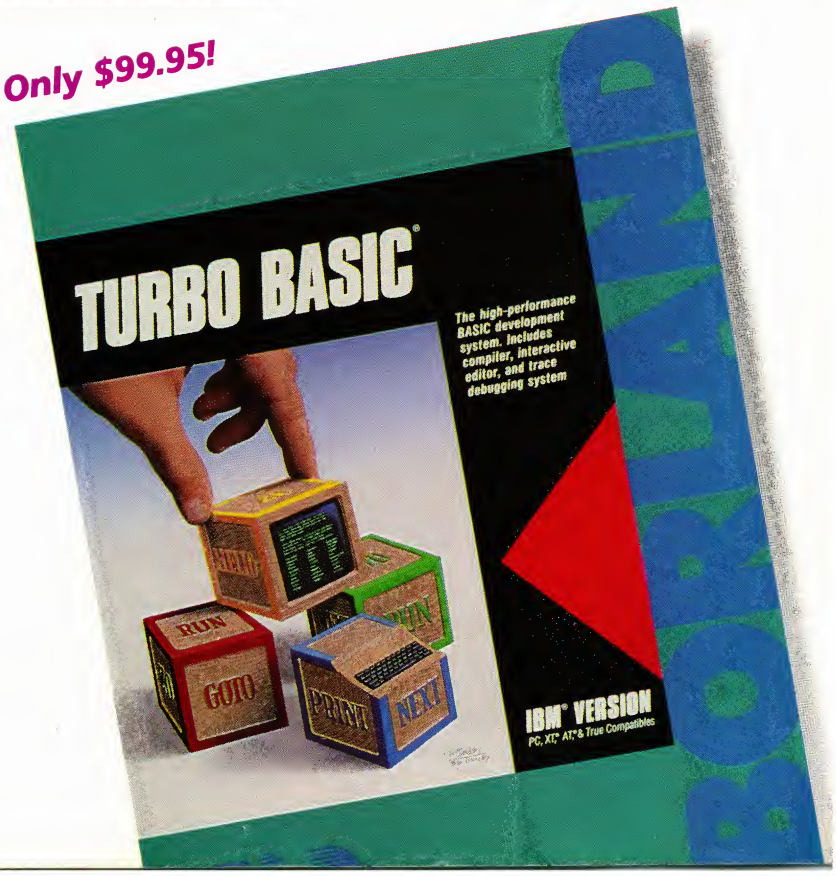

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Turbo C®

Turbo C: The fastest, most efficient and easy-to-use C compiler at any price

Compilation speed is more than 7000 lines a minute, which makes anything less than Turbo C an exercise in slow motion. Expect what only Borland delivers: Quality, Speed, Power and Price.

Turbo C: The C compiler for amateurs and professionals

If you're just beginning and you've "kinda wanted to learn C," now's your chance to do it the easy way. Like Turbo Pascal, Turbo C's got everything to get you going.

If you're already programming in C, switching to Turbo C will considerably increase your productivity and help make your programs both smaller and faster. Actually, writing in Turbo C is a highly productive and effective method—and we speak from experience. Eureka: The Solver and our new generation of software have been developed using Turbo C.

Turbo C: a complete interactive development environment

Free MicroCalc spreadsheet with source code

Like Turbo Pascal and Turbo Prolog, Turbo C comes with an interactive editor that will show you syntax errors right in your source code. Developing, debugging, and running a Turbo C program is a snap.

Turbo C: The C compiler everybody's been waiting for. Everybody but the competition

Borland's "Quality, Speed, Power and Price" commitment isn't idle corporate chatter. The $99.95 price tag on Turbo C isn't a "typo," it's real. So if you'd like to learn C in a hurry, pick up the phone. If you're already using C, switch to Turbo C and see the difference for yourself.

System requirements

IBM PC, XT, AT and true compatibles. PC-DOS (MS-DOS) 2.0 or later. One floppy drive. 320K.

Technical Specifications

- ☑ *Compiler: One-pass compiler generating linkable object modules and inline assembler. Included is Borland's high performance "Turbo Linker." The object module is compatible with the PC-DOS linker. Supports tiny, small, compact, medium, large, and huge memory model libraries. Can mix models with near and far pointers. Includes floating point emulator (utilizes 8087/80287 if installed).*
- ☑ *Interactive Editor: The system includes a powerful, interactive full-screen text editor. If the compiler detects an error, the editor automatically positions the cursor appropriately in the source code.*
- ☑ *Development Environment: A powerful "Make" is included so that managing Turbo C program development is highly efficient. Also includes pull-down menus and windows.*
- ☑ *Links with relocatable object modules created using Borland's Turbo Prolog into a single program.*
- ☑ *ANSI C compatible.*
- ☑ *Start-up routine source code included.*
- ☑ *Both command line and integrated environment versions included.*

*Introductory price—good through July 1, 1987

Sieve benchmark (25 iterations)

	Turbo C	Microsoft® C	Lattice C
Compile time	**3.89**	16.37	13.90
Compile and link time	**9.94**	29.06	27.79
Execution time	**5.77**	9.51	13.79
Object code size	**274**	297	301
Price	**$99.95**	$450.00	$500.00

Benchmark run on a 6 Mhz IBM AT using Turbo C version 1.0 and the Turbo Linker version 1.0; Microsoft C version 4.0 and the MS overlay linker version 3.51; Lattice C version 3.1 and the MS object linker version 3.05.

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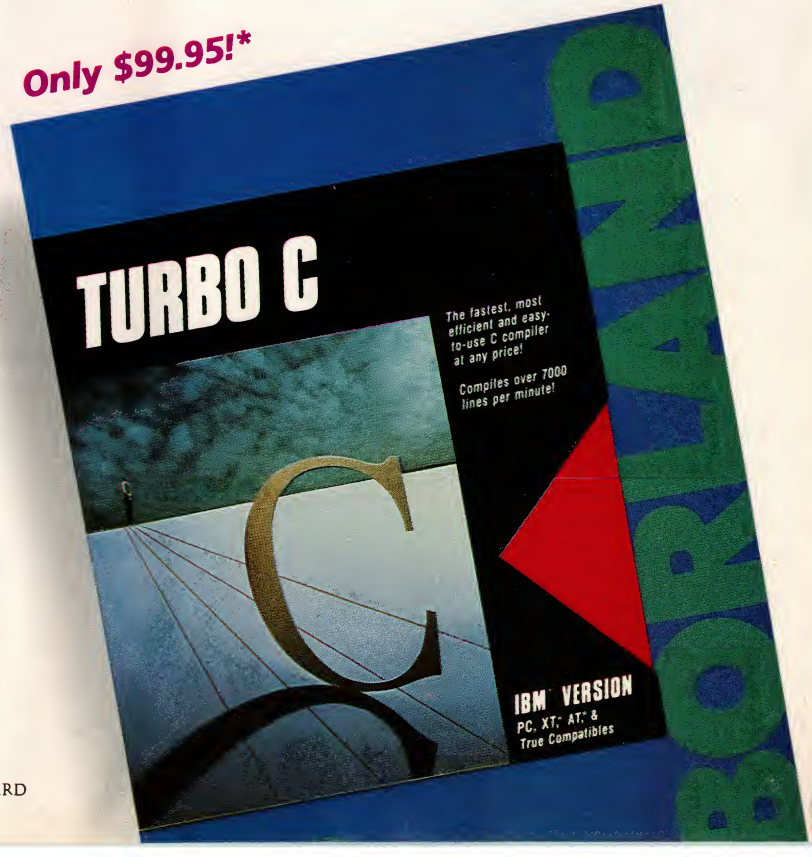

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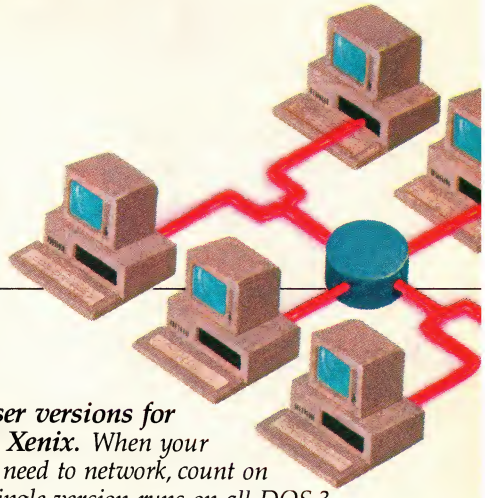
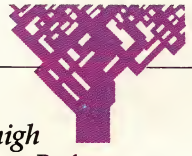


When you're serious about application development, there's just one choice for file management: Btrieve. With what *Computer Language* calls "near mainframe functionality[1]", Btrieve sets the file management standard for PC applications. With Btrieve loaded in your PC, your programs can use simple subroutine calls to retrieve, store and update records.

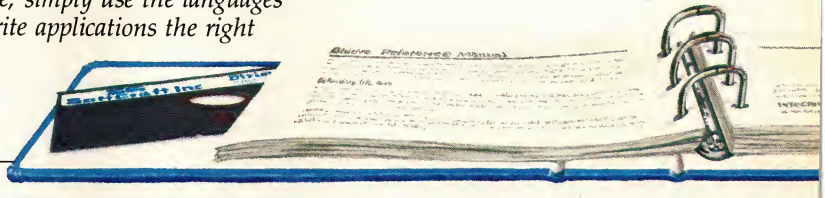
Multi-user versions for LANs and Xenix. *When your applications need to network, count on Btrieve. A single version runs on all DOS 3 LANs, including IBM PC Network and Novell Advanced Netware. Btrieve is also available for Xenix and multitasking operating systems such as MultiLink Advanced, Microsoft Windows and IBM Topview.*



B-tree based for high performance. *Performance is all-important, especially as your database grows. That's why Btrieve implements the b-tree file structure—the fastest, most efficient method of accessing data.*

Interfaces to C, BASIC, Pascal, COBOL. *Don't waste time programming in awkward fourth generation languages! With Btrieve, simply use the languages you know best—and write applications the right way. Over 15 language interfaces available.*

Built-in security features. *Lock up sensitive data with Btrieve's password protection and unique data encryption scheme—especially useful in local area networks.*



Help is just a phone call away. *Need technical support? You've got it! Btrieve users receive 30 days of unlimited phone support at no charge. This "Direct Connect" policy is renewable for a full year at low cost. And try SoftCraft's free bulletin board for technical tips, seven days a week.*

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Database queries, report writing. *Add Xtrieve™ to your Btrieve applications for a fully-relational DBMS. Xtrieve's menu-driven interface gives your users the on-line query capabilities they need—without programming. Add our report writer option to produce custom reports and forms.*

No royalties.
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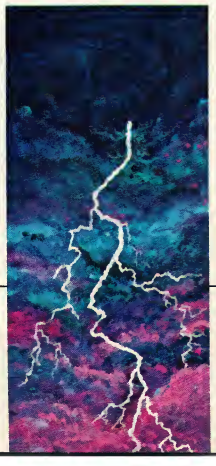

SoftCraft

P.O. Box 9802 #917 Austin, Texas 78766 (512) 346-8380 Telex 358 200

Suggested retail prices: Btrieve, $245; multi-user Btrieve, $595; Xtrieve, $245; multi-user Xtrieve, $595 (for report generation, add $145 for single-user and $345 for multi-user). Available from SoftCraft and selected distributors. Requires PC-DOS or MS-DOS 2.X, 3.X, Xenix. Btrieve is a registered trademark and Xtrieve is a trademark of SoftCraft Inc. [1]From Computer Language, *November 1985.*

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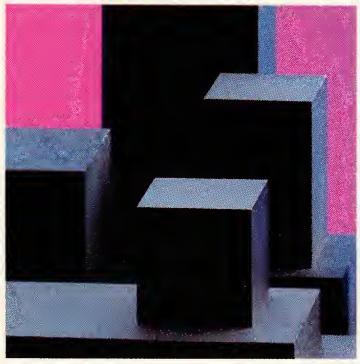

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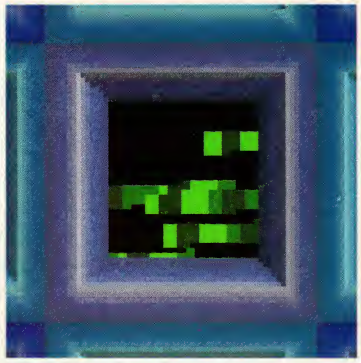

Mapping PC Address Space 102

Compatibility and Performance: **THE NEW STANDARD** / STEVEN ARMBRUST and TED FORGERON
No longer content to wait for IBM, Compaq introduced the Deskpro 386, the first AT compatible to house the Intel 80386. Our tests show that this Compaq is the fastest on the market and holds great promise for the multitasking programs of the future. 48

Compatibility and Performance: **UPDATING THE EVALUATION SUITE** / TED FORGERON, PAUL PIERCE and STEVEN ARMBRUST
To keep up with advancing technology, *PC Tech Journal*'s compatibility and performance metrics have been revised so that they can identify the processor in the test machine—8086/88, 80286, or 80386—and evaluate performance accordingly. 70

MULTILEVEL DEBUGGER / MARK S. ACKERMAN
With CodeView, Microsoft has improved on its line-oriented debuggers, DEBUG and SYMDEB, by offering full debugging capabilities at both the source code and assembly levels. CodeView is packaged with Microsoft's C and FORTRAN compilers. 90

MAPPING PC ADDRESS SPACE / AUGIE HANSEN
Several maps of memory and I/O addresses serve as a guide to inner space for programmers and hardware designers who need to know where the important hardware elements of the PC are located and where new ones can be safely placed. 102

MODULAR DEVELOPMENTS / JOHN T. COCKERHAM
Niklaus Wirth's latest contribution to the field of computer languages boasts the strongest typing and structured syntax yet, along with flexibility and low-level accessibility. Six Modula-2 compilers present a variety of choices for the systems developer. 114

BINARY TRANSFER / RONALD FLORENCE
The XMODEM protocol, considered the norm in PC-to-PC communications, can be adapted to transmit files between DOS and UNIX systems. Code is presented for producing a stand-alone remote XMODEM program for UNIX systems. 144

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Cover photograph · Marc David Cohen

Software Tools

For Programmers & Non-Programmers

Get 'State of the Art' performance and save valuable time with these high quality utilities!

Opt-Tech Sort™

Opt-Tech Sort is a high performance Sort/Merge/Select utility. It can read, sort and write a file faster than most programs can even read the data. Example: 1,000 records of 80 bytes can be read, sorted and a new file written in less than 10 seconds (IBM XT). Opt-Tech Sort can be used as a stand-alone program or called as a subroutine to over 25 different programming languages.

All the sorting, record selection and reformatting facilities you need are included. A partial list of features includes: The ability to process files of any size. Numerous filetypes are supported including Sequential, Random, Delimited, Btrieve, dBASE II & III and many others. Up to 10 key fields can be specified (ascending or descending order). Over 16 different types of data supported. Powerful record selection capability allows you to specify which records are to be included on your output. Record reformatting allows you to change the structure of your output record and to output special fields such as record numbers for use as indexes.

MS-DOS $149. ★ NEW ★ Xenix $249.

★ NEW ★ VERSION On-Line Help™ ★ NEW ★ VERSION

On-Line Help allows you to easily add "Help Windows" to all your programs. On-Line Help is actually two help packages in one. You get BOTH Resident (pop-up) and Callable Help Systems.

The resident version allows you to add help to any system. Your Help System is activated when the "Hot Keys" that you specify are pressed. You can then chain between help windows in any manner you desire.

The callable version allows you to easily display help windows from your programs. A simple call to the help system makes the window appear. The original screen is automatically restored when the help window is cleared. On-Line Help is callable from over 20 different languages.

You have full control over the help window content, size, color and location.

MS-DOS $149. **Demo $10.** (apply toward purchase).

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Scroll & Recall is a resident screen and keyboard enhancement. It allows you to conveniently scroll back through data that has gone off the top of your display screen. Up to 27 screens of data can be recalled or written to a disk file (great for documenting systems operations). Also allows you to easily recall and edit your previously entered DOS commands without retyping.

Scroll & Recall is very easy to use. It's a resident utility that's always there when you need it. MS-DOS $69.

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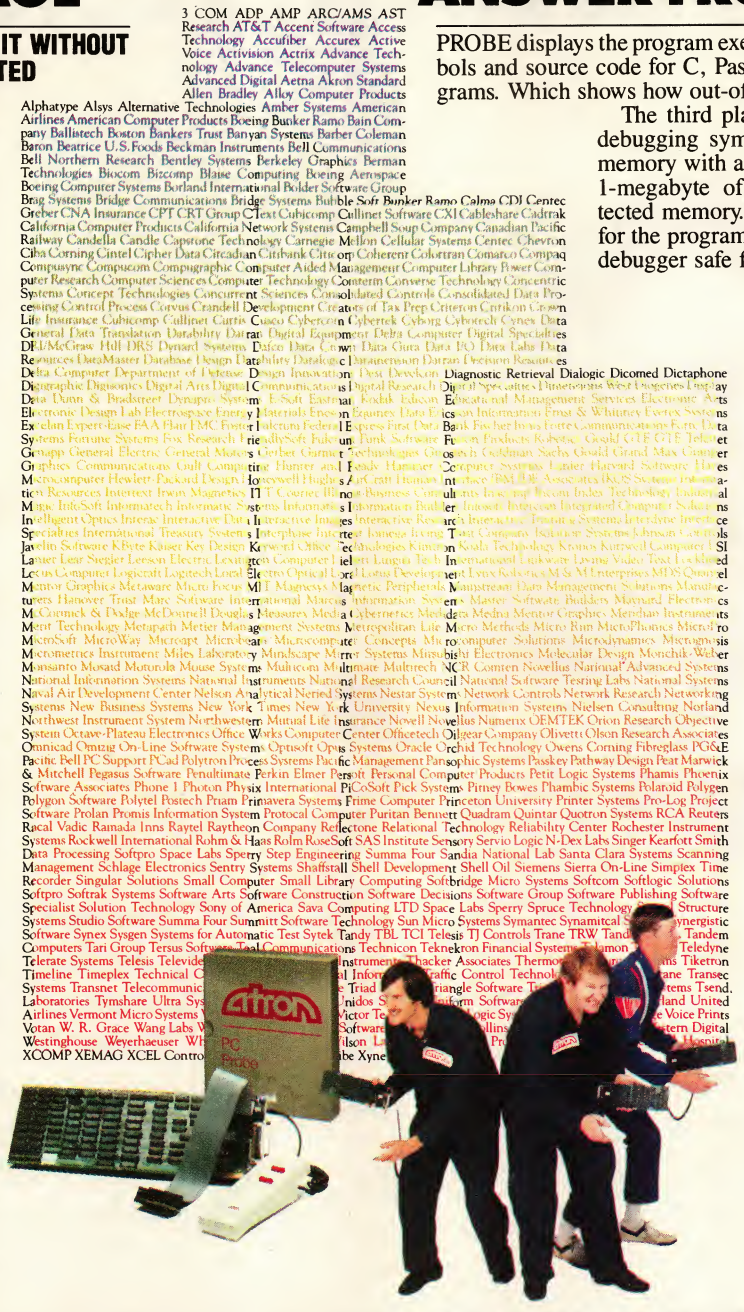
PLAGUES OF BIBLICAL PROPORTIONS

The first and most difficult plague was impossible to trap with software debuggers. These were carnivorous bugs which randomly overwrote programs, data, even the debugger. Nastiest were the ones that slipped in once every few hours, or changed their behavior after each new compile. Forty days and forty nights of recompiling, *trying something else*, caused many a would-be resident of the city to run screaming into the wilderness, never to be heard from again.

Second came the plague of not knowing where the program was, or where it had recently been. This compounded the first plague: How could anyone know *what* caused the random memory overwrites? Add to this random interrupts and timing dependencies, and you begin to understand *The Fear* that gripped the city.

Then came the last plague, which brought the wizards to their knees before they even started debugging. Their towering programs consumed so much memory, there wasn't enough room for their symbol table, let alone debugging software. Even if they could get past the first two plagues, this one killed their firstborn software.



PROBE displays the program execution in detail, including symbols and source code for C, Pascal, or assembly language programs. Which shows how out-of-range pointers got that way.

The third plague, not enough room for the debugging symbol table to be co-resident in memory with a large program, was cured with 1-megabyte of on-board, hidden, write-protected memory. System memory was then free for the program, keeping the symbol table and debugger safe from destruction.

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CIRCLE NO. 203 ON READER SERVICE CARD

Performance Metrics

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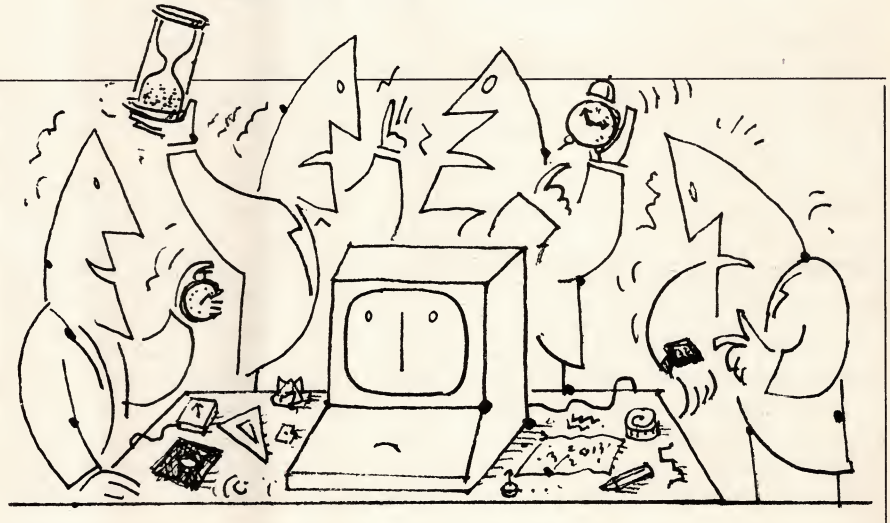

ILLUSTRATION • MACIEK ALBRECHT

Since the day that Peter Norton introduced his now-famous and ubiquitous system information utility, SI, we have all been swept away by a passion for quantifying the performance of the computers on our desks. Our compulsions may be well-founded. Justifying the purchase of advancing technology, is often difficult, especially in the face of plummeting PC prices; the raw performance of the latest model can be a significant selling point.

Norton's SI was a good measure at the time it was introduced, but the hardware technology has moved well beyond what SI is capable of measuring. In fact, it disturbs me that SI continues to be so frequently used, especially by hardware vendors, because it can actually be quite misleading. If the problem were simply measuring 8088 processors that were getting faster and faster, SI would serve perfectly. The fact of the matter is that today's machines might be equipped with any member of Intel's 86-family of processor, from 8088 to 80386; a numeric coprocessor; memory capable of operating with zero wait states, or just plain faster memory; different (from the PC) memory organization; a cache memory system; a higher-bandwidth disk-drive subsystem; a non-AT bus; or an intelligent display adapter. The machine might even have an accelerator product with some combination of the aforementioned features. All these features affect performance in ways that a simple program cannot hope to measure reliably.

SI is not the only benchmark whose contemporary validity I question. Many benchmark programs attempt to mimic the operation of particular types of applications. For example, a benchmark might attempt to measure compute-bound applications or disk-intensive applications or those with some mix of the two. Actually, benchmarks that measure processor- or disk-bound performance are usually valid. The problem is that most computer programs have their own, unique fingerprint where the use of system resources is concerned. No "standard" benchmark will ever properly illuminate the performance of unique programs.

To avoid this problem, another type of benchmark measures the performance of a specific program so that its operation may be compared on different computers. The most common is the "typical" Lotus 1-2-3 spreadsheet. This might seem to be a reliable metric because it does indicate how well the machine will fare as a 1-2-3 engine; *PC Tech Journal* uses metrics of this type to measure language compiler performance. However, such tests shed little or no light on the raw performance of the underlying hardware—the very thing we want to measure in our reviews of 80286 and 80386 machines. In fact, this type of benchmark usually masks the performance capabilities of advanced hardware because most programs such as 1-2-3 or compilers are written for the lowest common denominator—the 8088—and, therefore, they may not show an 80386-based machine in its best light even if the observed performance is superior.

Worse, programs written for prior architectures sometimes suffer on the newer machines because they exploit the dark recesses of the older machine's capability; on the newer architecture, some of these "features" become suboptimal. Once again, typical benchmarks usually fail to identify such conditions and any performance degradation becomes invisible if the test computer is faster in other ways.

NEW, IMPROVED!

PC Tech Journal has long recognized this problem. That is why we have taken a different approach in constructing the compatibility and performance metrics that we update in this month's issue ("Updating the Evaluation Suite," Ted Forgeron, Paul Pierce, and Steven Armbrust, p. 70). Our approach is difficult to program, but easy to describe. Rather than taking a single measurement, or reducing a set of observed measurements to a single number, Forgeron, Pierce, and Armbrust have produced an Evaluation Suite that measures the most important contributors to performance and reports the results *individually*. We thus leave the final conclusions to you, because only you can know the specific criteria that bear upon your particular situation and therefore understand which performance issues are germane.

We are going to stop referring to the Evaluation Suite as a set of bench-

marks. The term *benchmark* implies that the answer is somehow absolute and final. I prefer the term *metric*, because we are providing a set of tools that can be used for taking measurements. We consider those measurements excellent in each individual category, but we make no judgment about the performance of the system as a whole because, again, we cannot know the fingerprint.

Our metrics are good, perhaps the best currently available to measure AT-compatible computers. The improvements embodied in the updated code render the suite even more useful than before, although some of the changes are somewhat subtle.

The most significant change is to ATPERF, which now identifies the processor (8088, 8086, 80188, 80186, 80286, or 80386) and selects appropriate measurement techniques for each processor type. This means that the suite can be run on *any* PC and should deliver useful information. Alas, certain measurements cannot be taken on all processor types; in those cases, ATPERF simply does not report a result. One obvious change to the program is the processor-specific code; this was the only way to make valid measurements because of the architectural difference in the processors. ATPERF also has been extended to handle zero-wait-state memory, a feature that is becoming more and more common as hardware vendors attempt to make memory system performance match the rising processor speeds and as the price of faster DRAM chips drops.

READ THE LABEL!

Even though the *PC Tech Journal* compatibility and performance tests do not make judgments or report general indices of performance, each measurement must be understood. An anecdote illustrates the point.

A number of firms use our Evaluation Suite to demonstrate their AT-compatible computers. One demonstrator at Fall COMDEX was showing the difference in performance between his firm's machine and the standard AT. In almost every category, his machine outperformed the AT: However, ATPERF reported that his machine inserted more wait states for graphics board memory accesses than the AT, and he was apologizing to his audience for this, saying that the development team was "looking into the problem."

Of course, there was no problem at all. In each machine the graphics board was the same and *it*, not the processor, was constraining the operation. The graphics board required a fixed amount of realtime to perform its task; in the demonstrator's faster machine, this translated into *more* wait states. Had the demonstrator fully understood the meaning of the metric, he could have avoided the apologies and pointed to yet another indicator of higher performance. Indeed, I explained the meaning, and he changed his pitch.

Understanding each measurement is what allowed us to discover an anomaly in the measurements of the Compaq Deskpro 386. When we ran the program, the times for ROM reads seemed far too high. On closer inspection, it was discovered that the technique used to determine ROM timings (more fully described in the Deskpro 386 review on page 48) were fooled by Compaq's memory organization and the fact that the BIOS is not actually in ROM at the time the measurement is taken. We discovered this problem late in the publication cycle; the article and tables are updated to reflect proper timings, but our published code for ATPERF does not reflect a method for overcoming this particular problem.

This is not an 80386-specific problem. The metric is accurate for every machine we have tested *except* for the Deskpro 386. ATPERF provides accurate measurements on ALR's Access 386 machine, for example. The Compaq experience points out that even our metrics, good as they are, can be fooled by the implementation of techniques designed to improve memory performance. ATPERF's first black eye was the zero-wait-state memory of IBM's XT-286; the Deskpro 386's static column RAM is the second. In the future, cache systems and interleaving will undoubtedly cause similar difficulties. We also are concerned about the hybrid nature of systems with accelerator products; will our tests be valid for an AT with Intel's InBoard 386/AT installed?

The complexity of design and the variety of systems may prevent a general-purpose utility from being written. We hope this is not the case and are working to give ATPERF the ability to handle these new situations. However, special metrics may be needed for special cases, such as the Deskpro 386 and InBoard 386. If so, we will try to provide them.

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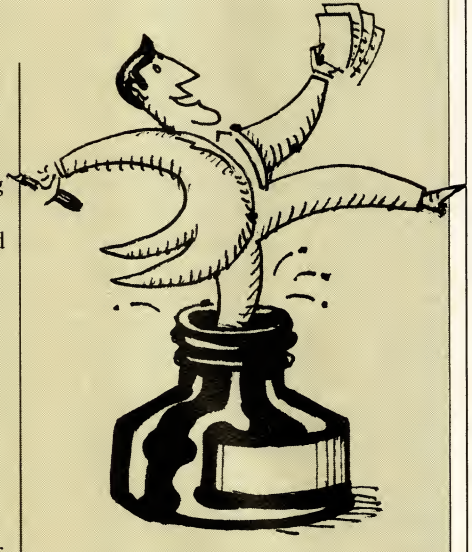

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*The benchmark procedure was adapted from "Benchmarking Database Systems: A Systematic Approach" by Bitton, DeWitt and Turbyfill, December 1983.

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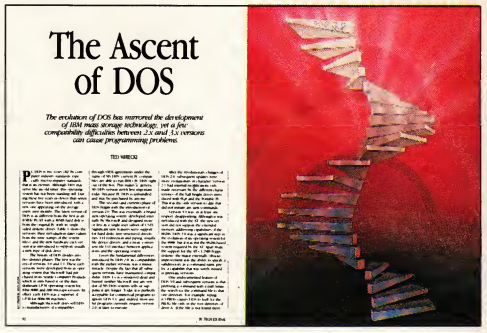
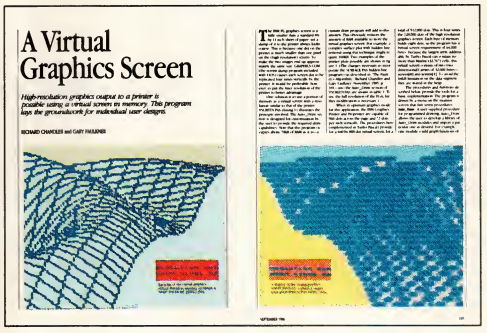

The Ascent of DOS

The evolution of DOS has mirrored the development of IBM mass storage technology; yet a few compatibility difficulties between 2.X and 3.X versions can cause programming problems.

TED MIRECKI


A Virtual Graphics Screen

High-resolution graphics output to a printer is possible using a virtual screen in memory. This program lays the groundwork for individual user designs.

RICHARD CHANDLER and GARY FAULKNER

MYSTERIOUS CHARACTERS

I have been using VSCREEN.PAS from your September 1986 issue ("A Virtual Graphics Screen," Richard Chandler and Gary Faulkner, p. 134), partly to learn something about Pascal.

I am ordering a back issue of the November 1985 *PC Tech Journal* for SURFACE.PAS ("The Painter's Algorithm," Richard Chandler and Gary Faulkner, p. 181) to use with VSCREEN. In the meantime, I have some questions regarding this program. In the past, when I have raised the point of possible typographical errors in printed listings, I have been assured that the listings are printed from actual computer print-outs of tested coding, and therefore, are unlikely to contain typesetting errors. However, my Pascal compiler, Turbo 3.0, hangs up on a line on page 145 of the article:

```
for y :=    to c do
```

It seems that a number is missing from this line, and if I put one in, the compiler proceeds, but I do not know what number should be there.

Also, two end statements appear without semicolons. This is something I had not seen before; however, the compiler complained when I added them, so I kept them out.

I also was unfamiliar with your use of the up arrow character (^) that appeared in several places. Does this have a specific meaning in Pascal?

Finally, in two places (on pages 141 and 142), in a very similar context, a character appears to be smudged in my copy. This character appears after the less-than symbol (<) in the line

```
gotoxy (14,18);
  write ('<    : Begins or Ends line');
```

This is an unusually complex and valuable program to be found in the public domain, and it is greatly appreciated.

Samuel S. Starr
Rose Valley, PA

Thanks to Mr. Starr for pointing out several problems with the program listing for VSCREEN.PAS. I had not noticed them before and one of them is crucial to running the program. The line that Mr. Starr mentions,

```
for y :=    to c do
```

should instead read

```
for y := 0 to c do
```

Turbo Pascal does not allow a semicolon (;) to precede an **else** *statement in the* ***if...then...else*** *clause. This is the reason for the missing semicolon following those end statements.*

In Pascal, the ^ (up arrow) character indicates a pointer variable (see chapter 15 in the Turbo Pascal manual). Because Turbo accommodates only a 64KB data segment, the virtual screen had to be stored in the heap, necessitating the use of pointers.

The characters that were not clear in the **gotoxy (a,b)** *statements were part of screen directions for these procedures. We were trying to produce something that looked like the symbol on the Enter key. We used the < (60), − (196), and ⊥(217) symbols for this.* PC Tech Journal *has changed the printer used for producing program listings and the software for font selection apparently was not completely bug-free when this listing was printed, thus a strange character (ái) was introduced into the listing. An error similar to this one appears on page 142 in the listing for procedure Write_to_Screen. The remainder of the line that begins*

```
gotoxy (10,12);
```

should actually read as follows

```
write('PgUp/PgDn Scrolls Up or Down ¼
  Screen');
```

We used the ¼ (172) character instead of writing one-fourth and wound up with a tilde (~) in the printed listing.

—Richard Chandler

DOS DISSENT

In his article "The Ascent of DOS" (October 1986, p. 92), Ted Mirecki misses the point about the problems with PC-DOS 3.2, which is, in fact, a radical departure from prior versions. One of the reasons PC-DOS computers are so popular is the ease of installation of most PC-DOS software, which depends on knowledgeable programmers controlling the environment in which their programs run. In version 3.2, IBM/Microsoft took some of that control (the hardware stack size) away from the programmer and gave it to the customer, who ends up calling the programmer to find out why he is getting stack overflow errors, and invariably blames the programmer for the problem. And yet, for all this trouble, version 3.2 offers no operational advantage over 3.1. Software companies should be outraged at IBM for causing such headaches, not to mention the telephone bills, and demand that stack management be returned to the control of the programmer.

James L. Larsen
Computer Consultants
Salt Lake City, UT

As PC-DOS matures and becomes more of a professional business-oriented operating system, it is inevitable that some measure of control is lost. Even in the current state of DOS, with ever more complex interactions between resident programs and a network environment, it is becoming less practical to leave system stack management within application programs. When a program is written, it is impossible to foresee its stack requirements under all of the possible conditions it may encounter. When and if an application fails, it is certainly simpler to tell users to modify a CONFIG.SYS file than to distribute recompiled versions of an application.

It might be argued that taking stack management away from the programmer is not absolutely necessary in

DOS 3.2, but we might as well get used to proper programming practices as soon as possible. The separation of memory, especially stack space, for system and application uses is the defining characteristic of protected-mode operation. Developers of software for upcoming protected-mode multitasking operating systems will have no choice but to relinquish some of the control they heretofore exercised over memory management. Such is the price of progress, but the payoff will be more powerful applications, and even more popularity for the next generation of DOS systems.

—Ted Mirecki

WELL-DIRECTED

After a brief inspection of the *PC Tech Journal Directory*, which includes the product guide, I can say that this issue alone is worth the yearly subscription. It is extremely valuable, well done, and very thoughtfully organized.

Pavel Vladu
Jersey City, NJ

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BACK TO SCROLLER

Strange things happen when I run SCROLLER.COM on my PC/AT. (See "Flicker-free Scrolling," Tech Notebook 67, Michael Abrash, September 1986, p. 43.) Basically, the machine hangs and requires a cold boot. I spent a lot of time entering the program and double-checking for my own typographical errors. I had zero errors and zero warnings with my IBM MASM 1.0. The linker gave the message "No stack segment," a length of 00193H, a name CSEG, and a program load at 0000:0100. EXE2BIN gave no errors or messages. Could it be a problem with a typo in the article listing, or a conflict with another resident color routine I have, or perhaps it is with the DDIR.COM program (from *PC Magazine*) that I use? Is the program load address correct?

I have an AT bumped to 8 MHz, a Hercules color graphics adapter, and I also load a Norton SA.COM color routine in my AUTOEXEC.BAT file with the ANSI.SYS installed in CONFIG.SYS. The machine boots just fine, the desired colors appear from the SA routine, and DDIR.COM works fine until I load SCROLLER.COM. Then the machine just hangs when I run DDIR.COM.

Flicker is one problem I really have always wanted to resolve. It has always seemed an annoying but simple bug that IBM should have addressed and solved before releasing the original PC and the CGA. This is why I really appreciated your SCROLLER.ASM program when it was published. Thank you for any suggestions you can provide.

William M. Ewers, president
American Progressive Life Insurance
Nashville, TN

Here is one reason (and perhaps a second) why SCROLLER does not work well for Mr. Ewers. The reason his system hangs is that SCROLLER must be converted to a .COM file with the command

EXE2BIN SCROLLER.EXE SCROLLER.COM

then SCROLLER.EXE must be deleted before SCROLLER can be run. Mr. Ewers was running the .EXE file, which is partially overwritten by the next program run (in this case, Mr. Ewers happened to run DDIR next, but any program would have had the same effect). I am afraid that in the interests of saving space I neglected to spell out the correct use of EXE2BIN here.

A possible reason why his screen still flickers after SCROLLER is loaded is that SCROLLER does not eliminate flicker for the CGA, but only for dual-ported

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CGA clones. This means that SCROLLER will not work if the Hercules card is not dual-ported. Mr. Ewers may have been misled by the title for this Tech Notebook, which originally was "Flicker-free Scrolling for CGA Clones." In addition, the introductory blurb should have stated that SCROLLER worked only with CGA clones. I apologize for any inconvenience this has caused.

—Michael Abrash

THE TERMINATOR

In the November 1986 issue of *PC Tech Journal*, the article "Prolog Arrives" (Michael Covington and Andre Vellino, p. 52) gives the following predicate definition that "counts the number of elements in a list. . ."

```
length([],0).
length([H|T],N) :-
    length(T,M),
    N is M + 1
```

and states that "if the terminating condition were written after the recursive part, the program would not terminate." This simply is not the case. This definition can be found in Leon Sterling and Ehud Shapiro's book *The Art of Prolog* (The MIT Press, 1986) on page 131. Either ordering of these rules will work for counting numbers in a list. The terminating condition is a goal such as

```
length([],X)
```

Such a goal will not unify with the head of the recursive rule, hence the recursive rule will not be used. The terminating condition rule would then be tried and the process would halt. In fact, placing the recursive rule first is *more* efficient. The reason is this: consider taking the **length** of a list of size *n*. The recursive rule is going to be used *n* times, whereas the terminating rule is only ever used once. Hence, it makes more sense to put the recursive rule first, saving the interpreter from trying the terminating rule *n* times. Perhaps the authors have in mind that if the recursive definition is placed first, then the definition is not suitable for other than the stated purpose—that is, counting the number of elements in a list, so that, for example, a call such as

```
length(X,2)
```

in which **length** is asked to generate a list of **length** 2, will indeed not terminate as desired.

Richard Denney
Schlumberger Well Services
Austin, TX

Mr. Denney's remarks are correct. Programmers should note, however, that while it is true, in general, that the order of clauses in a Prolog predicate is important, it does not matter in this particular case. This is because when the call to ***length([],M)*** *attempts to bind [] to [H|T], it will fail and try another clause (the program thus will not go into an infinite loop).*

A better example to illustrate the significance of ordering clauses is an alternative definition of ***length*** *in which the terminating condition is slightly different and where* ***cut*** *controls the flow of execution. The program*

```
length1([X],1).
length1([H|T],N) :-
    !,
    length1(T,M),
    N is M + 1.
```

will terminate successfully; however, the following program construction:

```
length2([H|T],N) :-
    !,
    length2(T,M),
    N is M + 1.
length2([X],1).
```

will fail to terminate.

—Andre Vellino

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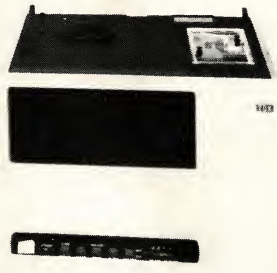

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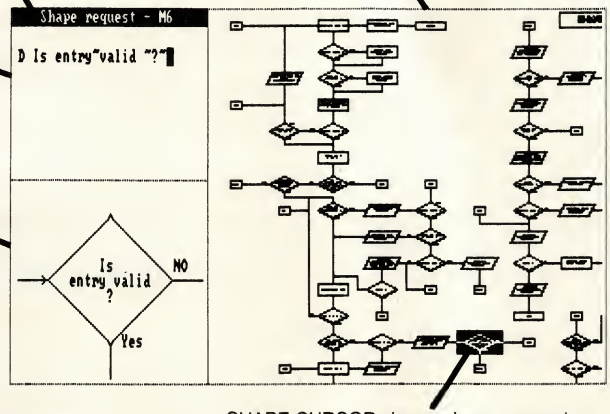

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LETTERS

THE ENGINE STALLED

I would like to apologize to those who had the interest to call or write for a software product I had developed, the BASIC ENGINE, which has been advertised in the Tech Book section of *PC Tech Journal* for the last few issues. I will not be able to directly market and support this product from now on and I will not be in a position to answer requests. I am sorry that I was unable to cancel the scheduled advertising in time to avert some calls.

I have version 2.0 of the BASIC ENGINE almost ready to ship, but will place it on the market on a "shareware" basis. Look for it on bulletin boards and through public domain software markets. Version 2.0 has a more enhanced editor that will allow screening for data types, case, and length, and allows formatting data better; it has an index file access method; and it has an excellent user-definable report generator.

Thank you again for your interest.

David A. Violette
Praxis Software Engineering
Green River, WY

A SUCCESSFUL EXPERIMENT

Back in 1983, *PC Tech Journal* published an article by Richard M. Foard on XB, Experimental BASIC ("The Anatomy and Construction of XB," July/August 1983, p. 61). That article was the most valuable tool that my company and I used for more than 18 months. I compiled your XB precompiler back then and made only minor alterations to increase its speed. It clocked in at about 266 lines per minute and we have used it since that time to develop between 50 and 100 XB-compiled programs with upwards of 2,000 lines each.

Now times have changed and most of the new program development we do is in the C language. However, we still have a lot of maintenance to do on what we have developed over the years, so we still use XB. Some people might believe that the new Microsoft QuickBASIC compiler has reduced the usefulness of XB, but that is not the case. The new compiler balloons the code so much, that we are sticking to our original IBM BASIC compiler. But even at 266 lines per minute, when processing a 2,000-plus line program, XB seems slow. So I have recently rewritten XB in the C language. Our new version of XB clocks in at 666 lines per minute.

Again thank you for the fine coverage of Experimental BASIC.

Douglas Hill
Glendale, MO

MICROSOFT LANGUAGES NEWSLETTER VOL. 2, NO. 3

News about the Microsoft Language Family

Tracing through User Libraries with Microsoft® QuickBASIC

Large programs are easier to maintain and debug if they are divided into smaller, more manageable parts. These units are called modules and may contain up to 64K of subprograms. You may separately compile subprograms with Microsoft QuickBASIC and build user libraries of these BASIC subprograms as well as assembly language routines. These user library routines can be used over and over again and are linked into your BASIC programs as needed.

Debugging these user libraries is made very simple with the built-in debugger in Microsoft QuickBASIC. QuickBASIC's built-in Debugging mode allows you to control the rate of program execution and the number of source lines displayed during execution. The Debugging mode is activated when the TRON statement is executed and is turned off with the TROFF statement. You can activate the Debugging mode for part or all of a source file. The Debugging mode has three "submodes": Step, Trace and Animate.

When you debug your BASIC programs that call subprograms contained in user libraries, Microsoft's QuickBASIC Debugging mode lets you trace through the user library routines when you activate the Trace mode. This mode traces program execution one line at a time like the Step debugging mode but you may also trace program execution through subprograms and user-defined functions. If you call any assembly language routines in your main program, the Trace mode will not trace through each line of the assembly routine but will trace the entire routine as a whole. Because the built-in debugger allows you to display both the source code and the output screen, you may observe the program execute while seeing the output.

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If you are a software developer who needs in-depth information, you may purchase Microsoft DIAL, an integrated set of on-line services. You can gain access to information on the DIAL bulletin board (which lists answers to frequently asked technical questions and provides information on new products, bug lists, seminars, and many other topics), and if the answer you are looking for is not on the bulletin board, you can electronically submit technical assistance requests (TARs) directly to Microsoft's support organization. Contact Linda McCarty at (206) 882-8080 for an application form and additional information on DIAL.

Filling out and sending in your product registration card is very important. It will allow you to receive notices about new versions and enhancements to your Microsoft product. The update notices let you know about the enhancements and instruct you on how you may receive the updated version. If you are in the market for a language product, you may receive useful information from this newsletter; you may also purchase a subscription to our Microsoft System Journal that contains technical articles on our languages and operating systems/environments. Microsoft Consumer Response can help you by sending you data sheets and other information such as the Language Support Directory (for available third-party libraries that support Microsoft languages).

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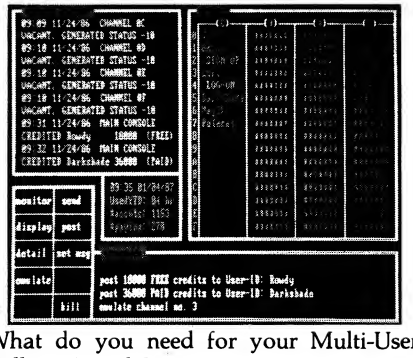

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LETTERS

MERGING TRAFFIC

Peter G .Aitken's interesting review of hard-disk cards for the PC in your January 1987 issue ("Mass-Storage Mergers," p. 76) contains an error in the two BASIC programs listed for verification of the ROM BIOS version. For the IBM PC, the program reads

```
10 DEF SEG&HF000
20 FOR X&HFFF5 TO &HFFFC
30 PRINT CHR$(PEEK(X));
40 NEXT
```

and for the Compaq Portable, the article lists the program as

```
10 DEF SEG&HF000
20 PRINT CHR$(PEEK(&HFFE6));
```

In both programs, line 10 should read instead as the following:

```
10 DEF SEG = &HF000
```

Running either program as listed by Mr. Aitken will result in a syntax error message in line 10.

Guillermo Hakim
New York, NY

Thank you for your corrections to the BIOS check listing for the two machines. Line 20 in the IBM PC check should be changed as well, to read

```
20 FOR X = &HFFF5 TO &HFFFC
```

Please also note some other corrections to this article's table of benchmark results (table 3, located across pages 84 and 85). First, under Measured Data, the overall average for the AUTOTEST random 8-sector read (0.90 width) actually should be 185.8

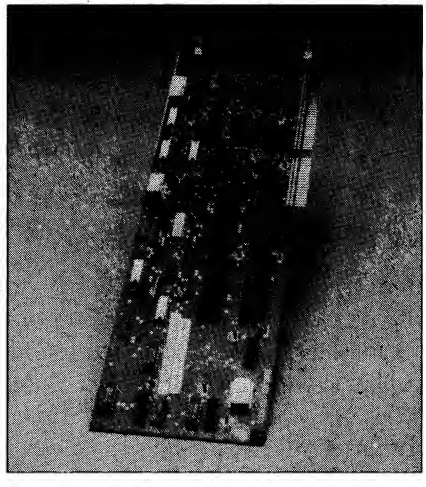
Under the next section, Percentage of Average Performance, several clarifications should be noted. First, the average of random tasks for the Mountain Computer card should say 83. Next, the unit measure for the ATDISK effective transfer rate should read milliseconds/KB (ms/KB)—designed so that a smaller number indicates a better performance (consistent with the remainder of the table). Also, to correct a computational error, the actual results for this test can be obtained by dividing the figures printed by 1.09.

Finally, the averages at the bottom of the table are computed as follows. The average for random tasks is obtained as an average of two items: (1) taking the average of random tasks in ATDISK, that is, the average seek time and the track-to-track seek time, and (2) the average of all eight random tests. The average of sequential tasks is obtained as an average of two items: (1) taking the average of sequential tasks in ATDISK, that is DOS file I/O and effective transfer rate, and (2) the average of sequential tests. The overall is an average of the average random and the average sequential results. Although the differences in the ATDISK effective transfer rate results (mentioned above) affect the sequential tasks average as well as the overall average, the conclusions that were drawn based on the results remain the same.

—Peter G. Aitken

ERRATA

The board that appeared in photo 13 (on page 62) of "RT PC: A Significant Departure" (Thomas V. Hoffmann, December 1986, p. 56) is actually the RT Monochrome Display Adapter, not the RT Multiport Communications Adapter (MCA). The MCA is pictured below.



In "Photo Plotting," the sidebar to "End-to-End Design" (Richard Angell, December 1986, p. 155), the first sentence of the second paragraph should say "With the introduction of computer-aided design (CAD), handtaping *is replaced by* pen plotting."

COMMENT AT WILL

All letters to the editor should be directed to Editor, *PC Tech Journal*, Suite 800, 10480 Little Patuxent Parkway, Columbia, MD 21044. Correspondence also can be submitted over MCI Mail to PCTECH.

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A. Bruce Cyr
Foundation of American College of Health Care Administrators

CIRCLE NO. 151 ON READER SERVICE CARD

The fastest, tightest code.

(Though the same can hardly be said of the name.)

We have to tell you, we had a hard time getting the name down this short.

Because Microsoft's new FORTRAN Compiler actually has a far longer list of features.

It uses the same optimizer and code generator technology that made our C Compiler the industry leader.

And we've added special loop optimizations that give you the smallest, fastest FORTRAN code a PC can handle.

> *"Now Microsoft's FORTRAN Optimizing Compiler generates such fast code that an IBM PC/XT approaches the speed of the VAX."*
>
> *Peter Osgood, MIT, Project Athena, Director of the Real Time Lab Project.*

This compiler has already passed the toughest test there is. It's been

Microsoft FORTRAN Optimizing Compiler Version 4.0.

- Full ANSI FORTRAN 77 Compiler with Fastest Executable Code for MS-DOS. NEW!
- Uses the Microsoft C optimizing technology, plus loop optimization. NEW!

Execution Speed (in Seconds)	Microsoft FORTRAN v. 4.0	Ryan-McFarland FORTRAN v. 2.11	IBM Professional FORTRAN v. 1.22
Sieve	7.97	9.33	38.51
Whetstone	53.82	58.67	79.04
Lookup	5.82	18.61	26.02

- Fully GSA certified for ANSI 77 compatibility with no errors at the highest level. NEW!
- Numerous IBM VS and DEC VAX extensions. NEW!
- Microsoft CodeView: Window-oriented source-level debugger. NEW!
  - —Debug using your original source code, the resulting disassembly or both intermingled.
  - —Watch and change the values of your local and COMMON variables as you debug.
  - —Set conditional breakpoints on variables, expressions or memory; trace and single step.
  - —Watch and change registers and flags as you execute.
  - —Easily debug graphics oriented programs since program output is kept separate from debugger output.

GSA-certified as Full ANSI FORTRAN 77, and 100% error-free.

"The Microsoft FORTRAN Optimizing Compiler let us port the 200,000 line Boeing Mathematical Library (BCSLIB) with virtually no changes. This ANSI FORTRAN 77 code was ported directly from Cray, CDC, DEC, IBM and other mainframes and workstations."

Ivor Philips, Boeing Computer Services, Program Manager Mathematical Software Libraries.

Compiler v. 4.0 with CodeView™

We've also included the same advanced intrinsic math functions found on VAX® and IBM® VS systems. Add improvements like our new HUGE memory model, and porting the biggest mainframe programs has never been easier.

Among the many additions we've made to our package is our exclusive CodeView™ windowing debugger. It lets you trace through programs at any level you want, from source code to assembly language.

You can open windows, and watch both variables (local and COMMON) and CPU registers change. You can set conditional breakpoints using variables and expressions.

Debugging gets even easier with the compiler's advanced diagnostics. Detailed error messages are thoroughly explained and cross-referenced in our new manuals.

Documentation that has been completely revised and expanded with tons of examples.

If we're talking your language, use one of the numbers below for more details about the Microsoft® ANSI FORTRAN 77 Optimizing Compiler Version 4.0 with CodeView, and the name of your nearest dealer.

(Even if the call's toll-free, it may be a good idea to refer to it as "FORTRAN 4" for short.)

Microsoft® FORTRAN

The High Performance Software.

Call (800) 426-9400. In Washington State or Alaska, (206) 882-8088. In Canada, (416) 673-7638.

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- Medium, Large and Huge Memory Model Libraries. NEW!
- Mix models with NEAR, FAR and new HUGE pointers.
- Common blocks and arrays greater than 64K.
- Choose from three math libraries and generate in-line 8087/80287 instructions or floating point calls:
  - —floating point emulator (utilizes 8087/80287 if installed)
  - —8087/80287 coprocessor support
  - —alternate math package—extra speed without an 8087/80287
- Link your FORTRAN routines with Microsoft C (v. 4.0 or higher), Microsoft Pascal (v. 3.3 or higher) or Microsoft Macro Assembler.
- Largest number of 3rd party support libraries available.
- Provides more detailed diagnostic error messages (almost twice as many as competitors) and extensive documentation with non-ANSI 77 features highlighted. NEW!
- Proven reliability—tested with over 2.5 million lines of code compiled and executed.
- MS-DOS® network support with file/record locking and sharing.
- Microsoft Program Maintenance Utility rebuilds your applications after your source files have changed. NEW!
- Other utilities including faster overlay linker (links over 1Mbyte object code), library manager, EXE file compression utility, EXE file header utility, MS-DOS environment setting utility and setup utility.

CIRCLE NO. 205 ON READER SERVICE CARD

The fastest C

Your search for execution speed is over. The new Microsoft® C Compiler Version 4.0 is here. With blazing performance. We've added common sub-expression elimination to our optimizer that produces code that rips through the benchmarks faster than ever before.

"...the Microsoft performance in the benchmarks for program execution is the best of the lot overall." —William Hunt, *PC Tech Journal*, January, 1986.*

But speed isn't the only edge you get with Microsoft C. Other advantages include a variety of memory models like our new HUGE model that breaks the 64K limit on single data items. Plus our NEAR, FAR and HUGE pointers, which provide you greater flexibility. All this allows you to fine tune your program to be as small and fast as possible.

"Excellent execution times, the fastest register sieve, and the best documentation in this review ...Microsoft Corporation has produced a tremendously useful compiler." —Christopher Skelly, *Computer Language*, February, 1986.

No more debugging hassles. Introducing CodeView. Free.

Now, for a limited time, we'll give you an unprecedented programming tool when you buy Microsoft C, free. New Microsoft CodeView™ offers the most powerful tool yet in the war on C bugs. Forget the hex dumps. Now you can view and work with programs at any level you want. Use the program source, the disassembled object code, or

Microsoft C Compiler Version 4.00

Microsoft C Compiler

- Produces fast executables and optimized code including elimination of common sub-expressions. NEW!
- Implements register variables.
- Small, Medium and Large Memory model libraries.
- Compact and HUGE memory model libraries. NEW!
- Can mix models with NEAR, FAR and the new HUGE pointers.
- Transport source and object code between MS-DOS® and XENIX® operating systems.
- Library routines implement most of UNIX™ System V C library.
- Start-up source code to help create ROMable code. NEW!
- Full proposed ANSI C library support (except clock). NEW!
- Large number of third party support libraries available.
- Choose from three math libraries and generate in-line 8087/80287 instructions or floating point calls:
  - floating point emulator (utilizes 8087/80287 if installed).
  - 8087/80287 coprocessor support.
  - alternate math package – extra speed without an 8087/80287.
- Link your C routines with Microsoft FORTRAN (version 3.3 or higher), Microsoft Pascal (version 3.3 or higher) or Microsoft Macro Assembler.
- Microsoft Windows support and MS-DOS 3.1 networking support.
- Supports MS-DOS pathnames and input/output redirection.

Microsoft Program Maintenance Utility. NEW!

- Rebuilds your applications after your source files have changed.
- Supports macro definitions and inference rules.

Other Utilities

- Library Manager.
- Object Code Linker.
- EXE File Compression Utility.
- EXE File Header Utility.

C Benchmarks

In seconds

	Microsoft C 4.0	Lattice C 3.0	Computer Innovation C 2.3	Aztec C86 3.2	Wizard C 3.0
Sieve of Eratosthenes (register)	82.9	151.4	172.3	88.0	91.9
Copy Block	86.9	231.7	199.0	123.8	189.5

Run on an IBM PC XT with 512K memory

Microsoft CodeView
Window-oriented source-level debugger. NEW!

- Watch the values of your local and global variables and expressions as you debug.
- Set conditional breakpoints on variables, expressions or memory; trace and single step.
- Watch CPU registers and flags as you execute.
- Effectively uses up to four windows.
- Debug using your original source code, the resulting disassembly or both intermingled.
- Use drop-down menus to execute CodeView commands.
- Access the on-line help to lead you through CodeView's options and settings.
- Easily debug graphics-oriented programs since program output is kept separate from debugger output.
- Keyboard or optional mouse support.
- Enter in familiar SYMDEB or DEBUG commands.

*Reprinted from *PC Tech Journal*, January 1986, copyright 1986, Ziff-Davis Publishing.

you've ever seen.

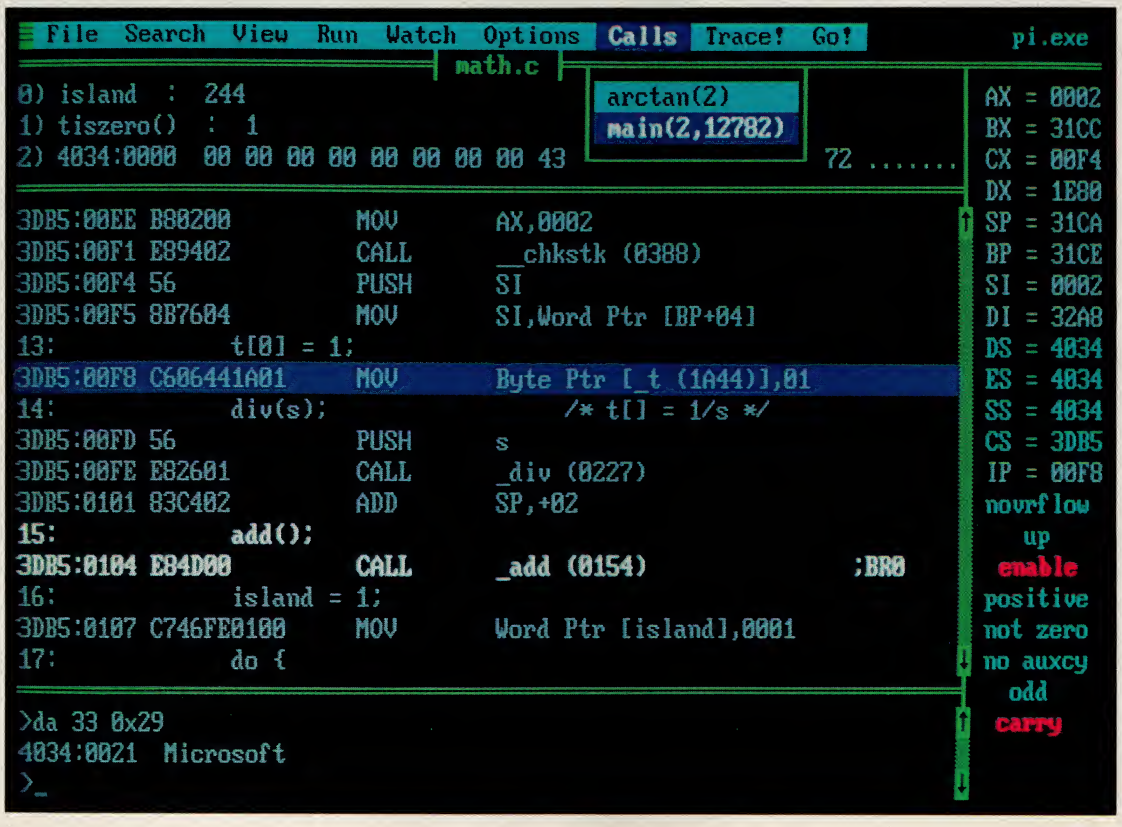
both at the same time. Open a window to view CPU registers and flags. Watch local and global variables as well. All while your program is running.

CodeView gives you complete control. Trace execution a line at a time—using source or assembly code. Or set conditional breakpoints on variables, memory or expressions. CodeView supports the familiar SYMDEB command syntax, as you'd expect. Commands are also available through drop-down menus. Combine the new window-oriented interface with our on-line help and debugging has never been easier. Or quicker.

Take the $5 CodeView tour.

You may find it hard to believe our debugger can do all we've claimed. So we're offering test drives. Five bucks will put you behind the wheel of a Microsoft C demo disk with CodeView.† See for yourself how fast debugging can get.

For more information about the CodeView demo disk, the new Microsoft C Compiler, a list of third party library support or the name of your nearest Microsoft dealer, call (800) 426-9400. In Washington State and Alaska, (206) 882-8088. In Canada call (416) 673-7638.



Microsoft® C Compiler

The High Performance Software

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CIRCLE NO. 140 ON READER SERVICE CARD

Finally, a language worth

For years BASIC has been everyone's first language. And for almost as long, they've been tempted by other languages. Lured by promises of more speed, more power.

We have a solution. A new language that's a substantial improvement over BASICA. Faster. More structured. Finally, a compelling reason to leave BASIC.

Introducing Microsoft's QuickBASIC Compiler, Version 2.0.

At last, you can have the latest programming techniques, combined with the solid foundation of BASIC. Our new compiler is as compatible with BASICA as you can get. At the same time it offers the extra speed and power you've been looking for.

Run faster with compiled code.

If there's one thing you've asked for, it's speed. And Microsoft® QuickBASIC simply blazes. Old BASICA programs will run up to ten times quicker once they've been compiled. Sometimes even faster.

Everything you need. Built-in.

Making programs run faster is only part of the story, though. The new Microsoft QuickBASIC Compiler includes a full-screen editor, built-in. So now you can make the jump from writing to RUNning in no time flat. Edit your program, compile it, and run it. Faster than any other BASIC compiler around. All without leaving our on-line help and prompts.

Microsoft is a registered trademark and The High Performance Software is a trademark of Microsoft Corporation. IBM is a registered trademark of International Business Machines Corporation.

leaving BASIC for.

On the rare chance your program doesn't run 100% the first time out, we've got another surprise for you. The Microsoft QuickBASIC debugger. Our full-screen tracing lets you debug your programs while watching the source code execute. A line at a time, or with breakpoints. As easy as can be.

Our compiler is also smart enough to save you time. First, by finding any errors in one pass. Second, by putting your editor's cursor on the problem. Automatically. So you don't have to get lost in a maze of error codes and line-numbers.

The BASIC virtues. And more.

Speaking of line numbers, let's not. Because line numbers are strictly optional. And Microsoft QuickBASIC lets you use alphanumeric labels as well. Now you can GOTO *ErrorCheck* instead of line number 6815.

Or you could stop using GOTOs altogether. There are a variety of options that could make the GOTO an endangered species. Features like multi-line IF-THEN blocks. And named subprograms. Now your BASIC programs can be as structured and organized as you want.

We've only just begun to talk about the virtues of Microsoft QuickBASIC. There are dozens of enhancements to your favorite language. Things like larger arrays. Local and global variables. Reusable modules that let you create libraries of your most often-used routines. All explained in a revised manual that includes a complete language reference.

Making your quick escape.

If all these features follow your BASIC instincts, then zip on down to your nearest Microsoft dealer. That's where you'll discover the best surprise of all. The price. Only $99 for the best reason to leave BASIC.

For the name of your nearest Microsoft dealer, call (800) 426-9400. In Washington State and Alaska, (206) 882-8088. In Canada, call (416) 673-7638.

Microsoft® QuickBASIC
The High Performance Software™

CIRCLE NO. 121 ON READER SERVICE CARD

Microsoft QuickBASIC Compiler Version 2.0 for IBM® PC and Compatible Computers.

BASICA Compatibility
- Sound statements including SOUND and PLAY.
- Graphics statements including WINDOW, VIEW, DRAW, GET, PUT, LINE, CIRCLE, LOCATE and SCREEN.
- Support of EGA extended graphics modes. NEW!
- BASICA structures are supported including WHILE/WEND, IF/THEN/ELSE, FOR/NEXT, GOSUB/RETURN, and event handling.

Results of Sieve Benchmark	BASICA 3.1	Microsoft QuickBASIC 2.0
Seconds per iteration	78	0.52

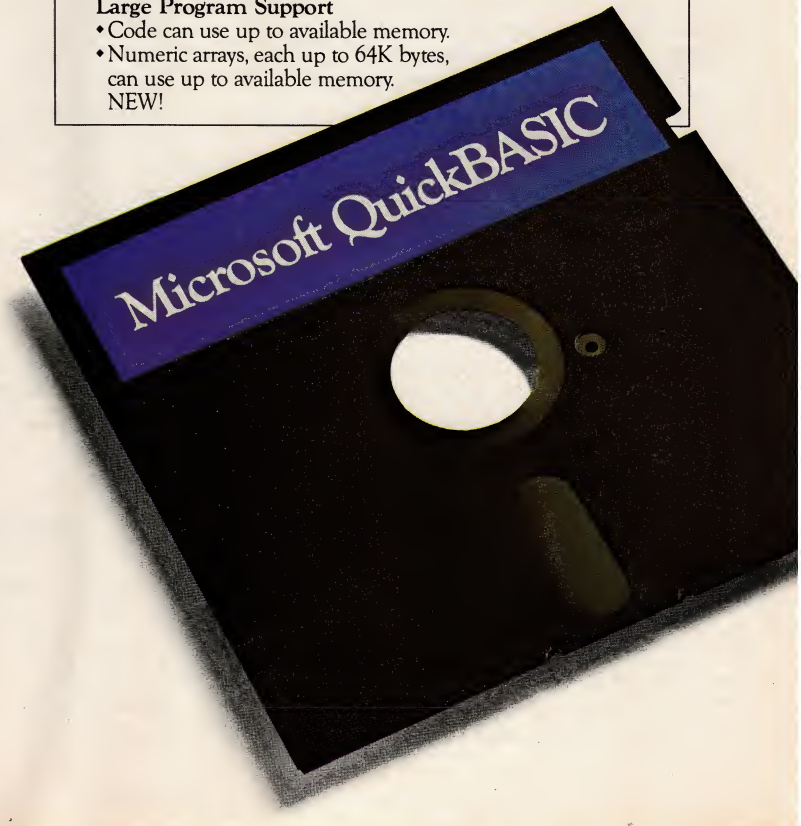
Complete Programming Environment
- Built-in Editor that places the cursor on found errors automatically. NEW!
- Compile entirely in memory at speeds up to 6000 lines per minute. NEW!
- Link routines once when starting a programming session and no need to link again when changing programs. NEW!
- Built-in debugger with single-step, animate, and trace modes. NEW!
- Create stand-alone programs.

Alphanumeric Labels
- Can be used to make your programs more readable. Line numbers are not required but are supported for BASICA compatibility.

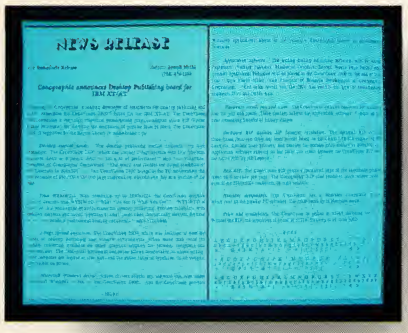
Structured Programming Support
- Block IF/THEN/ELSE/END IF eliminates the need for GOTO statements. NEW!
- Subprograms can be called by name and passed parameters. Both local and global variables are supported.

Modular Programming Support
- Separate compilation allows you to create compiled BASIC libraries to use and re-use your programs.
- A library of routines to access DOS and BIOS interrupts is supplied. NEW!

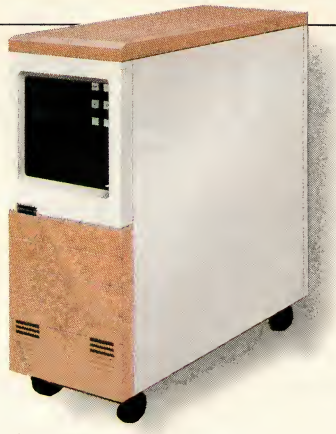
Large Program Support
- Code can use up to available memory.
- Numeric arrays, each up to 64K bytes, can use up to available memory. NEW!



Hardware, software, and other developments for the IBM PC family



Screen produced with Conographic's ConoVision 2800 board



PCMS Director from Racet Computes, Ltd.

HARDWARE

The **Net/One Universal Workstation Series** is a group of hardware and software products from **Ungermann-Bass, Inc.**, designed to develop a local area network (LAN) for corporate use.

The **Net/One 3270 NIUpc** network interface unit (NIU) adapter card enables a networked PC to run micro-to-mainframe applications that are written to the IRMA (Digital Communications Associates, Inc.) and IBM 3278/79 Emulation Adapter hardware (Ethernet baseband version, $1,495; broadband, 2,145). **Net/One 3270 PC** software enables a PC/XT or PC/AT to function as a full-featured, networked IBM terminal. Net/One 3270 PC supports as many as four 3270 terminal and printer sessions, two asynchronous terminal sessions, and one DOS application simultaneously. Full support for the IBM 3270 PC control program version 2.1 application program interface (API) has been added ($295 per workstation). **Net/One PC Graphics** software provides programmed symbol support for the Net/One 3270 PC and lets the user run as many as four concurrent IBM graphics sessions with an IBM CGA or EGA ($295 per workstation). **Net/One Async PC** is communications software that allows PCs to exchange data with asynchronous resources on Net/One. A set of terminal emulation products is included with the Net/One Asynch PC application program interface (API) to allow communication with a variety of minicomputers ($1,200 per server when bundled with Microstuf, Inc.'s Crosstalk XVI; $1,600 per server when bundled with Crystal Point, Inc.'s PCTERM—see SOFTWARE).

Working in conjunction with the Net/One PC software, the **Net/One NIUpc** adapter card provides server support for as many as 96 users, server support for diskless PCs, an extensive log-on security system that is embedded in network protocol, and a pop-up window utility that allows connections to Net/One resources to be made or deleted and network print queues to be viewed from within the PC application (Ethernet baseband version, $1,095; broadband, $1,745).

Ungermann-Bass also has introduced high-speed network bridges capable of linking local or geographically remote IBM-compatible token-ring LANs to an Ethernet network. Available in local and remote models, **Net/One Data Link Bridges** provide protocol-independent routing of data packets among multiple types of LANs. Bridges allow multiple communications protocols, such as Xerox Network System (XNS), Transport Control Protocol/Internet Protocol (TCP/IP), International Standards Organization (ISO), and Digital Equipment Corporation's DECnet to operate over the bridge. Both the 3Com Ethernet and IBM Token-Ring networks can run on high-speed T-1 telecommunications links between distant sites. All remote bridges operate from 4.8 Kbps to 2.048 Mbps. Baseband and broadband versions of these data link bridges range from $9,495 to $10,095. Software for each model is $2,000.

Ungermann-Bass, Inc., 3900 Freedom Circle, Santa Clara, CA 95052-8030; 408/496-0111

CIRCLE 301 ON READER SERVICE CARD

Racet Computes, Ltd. has announced an expansion of its **PCMS** (personal computer mass-storage) line of subsystems. The new products offer capacities of between 148MB and 870MB in a single enclosure. Four basic configurations are available: the **Administrator**, with 148MB formatted capacity; the **Supervisor**, with 200MB; the **Manager**, with more than 300MB; and the **Director**, with more than 400MB. Each configuration comes standard with 125MB streaming-tape backup capability. The ESMD controller operates at 2.4MB per second and has .5MB of cache memory that is expandable to 4.5MB. The average access time is 18 milliseconds (ms) for the Supervisor, Manager, and Director, and 25 ms for the Administrator. Prices range from $7,950 to $39,900; add-on 4MB cache, $3,750.

Racet Computes, Ltd., 1855 W. Katella, Suite 255, Orange, CA 92667; 714/997-4950

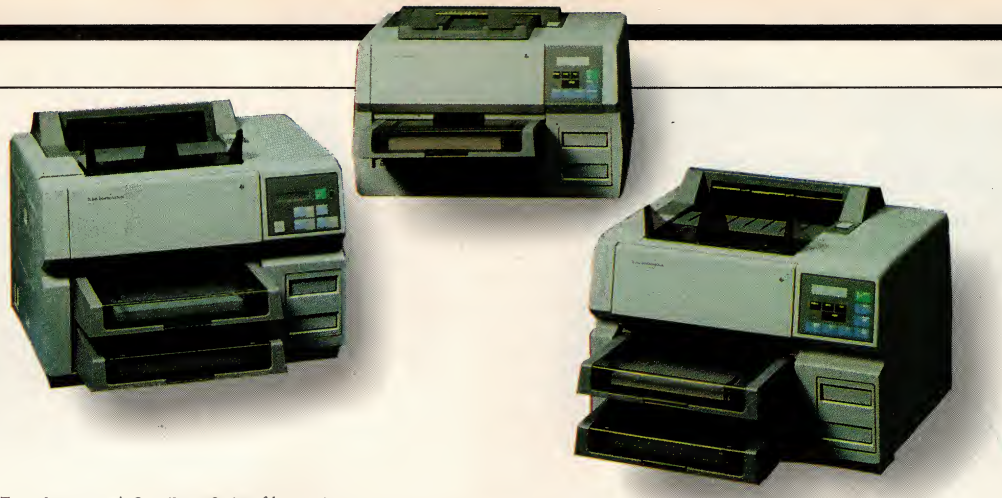
CIRCLE 310 ON READER SERVICE CARD

ConoVision 2800 is a desktop publishing board from **Conographic Corporation**. The board combines a high-resolution monochrome graphics adapter and a raster image processor (RIP) for doubling the resolution of popular laser printers. The ConoVision 2800 can display two-page spreads with true typefaces readable to as small as six points; it can double the output of Hewlett-Packard LaserJets to 600-by-300 dots per inch (dpi) and has a resolution up to 2,880-by-1,024 pixels. Screen drivers enable any software running under Microsoft Windows to run under ConoVision 2800. Hardware for scrolling, panning, and zooming is included. The board has a Hercules-compatible mode and drives 19-inch professional (100 MHz) and 15-inch high-performance (50 MHz) monitors. ConoVision 2800 with RIP, $1,985; without RIP, $1,325.

Conographic Corporation, 17841 Fitch, Irvine, CA 92714; 714/474-1188

CIRCLE 312 ON READER SERVICE CARD

Number Nine Computer Corporation introduces its **Pepper Graphics System** family with the **PEPPER PRO1280**. The PRO1280 combines the Number Nine Intelligent Operating System (a library of on-board, device-independent graphics, video control, and advanced memory-management functions) and the Memory Windows architecture, which allows mapping of IBM address space to the PRO1280 display or instruction memory, with Texas Instrument's TMS 34010



Texas Instrument's OmniLaser Series of laser printers

GSP graphics coprocessor. It combines noninterlaced 1,280-by-1,024-pixel resolution and 256 on-screen colors with IBM monochrome, CGA, and Professional Graphics Controller compatibility, in a single-board, single-monitor system. The board has 1.25MB of video RAM (expandable to 8MB), 128KB of instruction RAM, 128KB of graphics firmware, and either a 4,096- or a 16-million-color palette. The PRO1280 features a 16-by-38-pixel system font, as well as high display resolution. $3,000.
Number Nine Computer Corporation, 725 Concord Avenue, Cambridge, MA 02138; 617/492-0999
CIRCLE 307 ON READER SERVICE CARD

From **Epson America, Inc.** comes the **Image Scanner Option Kit**, an accessory for Epson's EX-800, EX-1000, and LQ-2500 dot-matrix printers. The scanner reads and converts hard-copy images into bit-image data, then transmits the data through a serial interface to a host computer where they are stored. The scanner offers a resolution of 180-by-180 dots per inch (dpi) on the LQ-2500, and 144-by-144 dpi on the EX series. A page of graphics can be scanned or digitized at 27 inches per second (ips) on the LQ-2500, and 25 ips on the EX series. $299.95.
Epson America, Inc., Computer Products Division, 2780 Lomita Blvd., Torrance, CA 90505; 800/421-5426; in California, 213/539-9140
CIRCLE 303 ON READER SERVICE CARD

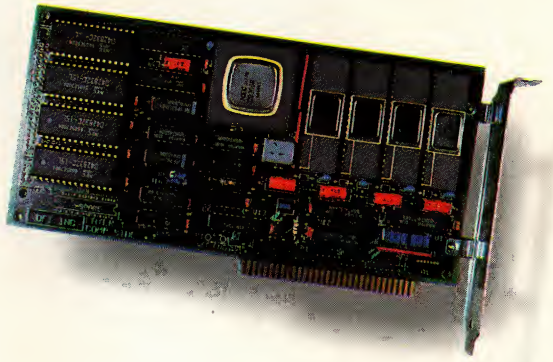
A family of laser page printers that is designed for shared resource environments, the **OmniLaser Series 2000**, has been announced by **Texas Instruments**. The **OmniLaser 2015** has a print speed of 15 pages per minute (ppm), a maximum-duty cycle of 25,000 pages per month, and a machine life of 1.5 million prints. The **OmniLaser 2115** uses the same 15-ppm print engine as the 2015; its PostScript controller with 3MB of RAM is built around the 32-bit Motorola 68000 chip. The **OmniLaser 2108** has an 8-ppm engine with a duty cycle of 10,000 pages per month, a 600,000-print machine life, and a 68000-based PostScript controller with 2MB of RAM. OmniLaser 2015, $5,995; 2115, $7,995; 2108, $5,995.
Texas Instruments, Data Systems Group, P.O. Box 809063, H-861, Dallas, TX 75380-9063; 800/527-3500
CIRCLE 304 ON READER SERVICE CARD

AST Research, Inc. has announced the **AST-5250/Gateway**, a single board with software that connects a LAN to an IBM System/3x machine. This gateway allows any LAN node to emulate 5250 terminal/printer sessions without an emulation card. The AST-5250/Gateway accommodates remote and local distribution systems in peer-to-peer or host communications link-ups. One microcomputer on the LAN is equipped with the AST 5251/11 Plus emulation card and a software package that distributes 5250 terminal/printer sessions to other nodes on the LAN. A maximum of three Gateways can coexist on the same LAN, and each Gateway can communicate simultaneously to a different host. Connections from the Gateway are made via standard twin-axial cable for local hosts or SNA/SDLC for remote hosts. $1,995.
AST Research, Inc., 2121 Alton Avenue, Irvine, CA 92714-4992; 714/863-1333
CIRCLE 313 ON READER SERVICE CARD

Three networking products have been introduced by **Racore Computer Products, Inc.** The **LANpac II**, a high-performance network system designed for Novell Advanced NetWare, can be connected in either a linear-bus or star configuration using coaxial or twisted-pair cable. It operates at selectable speeds of 4Mbit, 8Mbit, or 16Mbit per second. As many as 250 LANpac stations per cluster can be connected at a distance of up to 1,000 feet between stations. A **diskless workstation** incorporating optional LANpac circuitry for use in a PC/AT-compatible environment is available. An Intel 80286, operating at 10 or 12 MHz, provides AT performance. Available with LANpac directly integrated onto the main processor board, the workstation can accommodate as much as 2MB of memory. **LANpac 802.5** is a plug-compatible IBM Token-Ring adapter that can be incorporated into an existing IBM Token-Ring Network. LANpac 802.5 transfers data at the rate of 4Mbit per second using coaxial or twisted-pair cable. LANpac II, $295 per node; diskless workstation, $850 to $1,525; LANpac 802.5, $495 per node.
Racore Computer Products, Inc., 170 Knowles Drive, Los Gatos, CA 95030; 408/374-8290
CIRCLE 314 ON READER SERVICE CARD

Convergent Technologies has released several products for its network architecture, the **Cluster**. The **Series 386 NGEN** is an upgrade for current users of Convergent's NGEN workstations. Existing applications and peripherals are compatible with the new processor. **CTOS/VM**, a PC-compatible version of Convergent's distributed multitasking operating system, CTOS, supports multiple operating systems and their applications. It also provides support for 80286/80386 protected mode. The **ClusterCard**, which fits expansion slots on both the PC/AT and PC, and **ClusterShare** server software, provide network services, including electronic mail and resource sharing, to PCs over ClusterNet. **TeleCluster** piggybacks Cluster data on standard voice signals over existing in-house telephone wiring. The AT-compatible **Network PC** is designed to operate with or without local disk storage on the Convergent Cluster, 3 Com Ethernet, and other standard networks. Its built-in functions includes EGA video and up to 1MB of memory, in a desktop design. Retail prices are not applicable;

MultiTech Electronic's 80386-based MultiTech 1100 system



DF-1 coprocessor board from Data Flow Imaging, Inc.

all products are available in original equipment manufacturer (OEM) quantities and to value added retailers (VAR).
Convergent Technologies, 2700 N. First Street, P.O. Box 6685, San Jose, CA 95150-6685; 408/434-2848

CIRCLE 311 ON READER SERVICE CARD

A graphics board that is designed to run on the Sony Multiscan CPD 1302 monitor has been released by **QDP Computer Systems, Inc.** The **VIVA 1000/SCAN** with a resolution of 1,000-by-600 pixels and 16 simultaneous colors, displays a high-resolution, flicker-free image; it uses an NEC 7220A microprocessor. Features that are built into the board include hardware pan and zoom, and user-selectable cursors and colors, which are available via a single keystroke. The VIVA 1000/SCAN can be upgraded to QDP's 1000/16, which has a resolution of 1,024-by-1,024 pixels and drives 19-inch monitors. An available upgrade permits the display of 256 colors simultaneously from a palette of 16.8 million. Under $1,300.
QDP Computer Systems, Inc., 23632 Mercantile Road, Beachwood, OH 44122; 216/464-6600

CIRCLE 308 ON READER SERVICE CARD

Three low-cost interface boards that permit accurate monitoring and control of real world signals for the IBM PC, PC/XT, and PC/AT have been announced by **Real Time Devices, Inc.** The **AD500** and **AD100** are 12-bit analog input boards, and the **DG24** is a digital I/O board. All three boards are designed to fit into the PC's short slot. The AD500 has eight channels of 12-bit resolution and an on-board amplifier with software programmable gains of 1, 10, and 100. It can digitize analog input signals at 7.5 conversions per second—providing very high immunity to 60-cycle line noise. The software-selectable analog input ranges are ±5 volts, ±500 millivolts, and ±50 millivolts. The inputs are single-ended and are protected to 35 volts. Seven TTL-compatible digital lines can be configured as inputs or outputs and can be used to activate relays, sense switch closures, or control other external devices. The AD100 is a single-channel version of the AD500 with three additional I/O lines. The DG24 is a digital I/O board based on the 8255 peripheral interface chip with 24 TTL-compatible lines that can be configured in software as input or output lines. The board can be configured to support handshaking. Interrupts are jumper-selectable. AD500, $239; AD100, $149; DG24, $95.
Real Time Devices, Inc., 1930 Park Forest Avenue, P.O. Box 906, State College, PA 16804; 814/234-8087

CIRCLE 317 ON READER SERVICE CARD

A 16-MHz, 80386-based microcomputer has been introduced by **Multitech Electronics, Inc.** The **Multitech 1100** base system comes standard with 1MB of RAM on the motherboard, a 1.2MB diskette drive, a 40MB hard-disk drive with a 28-millisecond average access time, a diskette/hard-disk controller board, a battery-backed clock/calendar, one parallel and two serial ports, and a 101-key keyboard. The Multitech 1100 has space for five half-height 5¼-inch storage devices, a socket for an 80287/80387 numeric coprocessor, and eight expansion slots (two PC/XT-type, five PC/AT-type, and one 32-bit dedicated memory bus). Multitech 1100, $3,999; with 80MB hard disk, $5,995; with 130MB hard disk, $6,495; Multitech enhanced color graphics board, $379; enhanced color display, $599.
Multitech Electronics, Inc., 1012 Stewart Drive, Sunnyvale, CA 94086; 408/773-8400

CIRCLE 302 ON READER SERVICE CARD

The **GV-386**, a 16-MHz, 80386-based machine, has been introduced by **PC Designs, Inc.** Operating with zero wait states when the cache is enabled, the GV-386 uses standard DRAM rather than the static column RAM. The GV-386 meets the I/O bus timing of the 8-MHz PC/AT, to provide maximum compatibility with existing add-on boards. Some features include 64KB, 35-nanosecond (ns) to 45-ns static RAM cache circuit, an on-board cache circuit that can be enabled/disabled via keyboard toggle, switchable 8-MHz/16-MHz clock speed, and a specially designed AT-compatible BIOS that allows for operation of BIOS timing loops independent of CPU clock speeds. Bundled with the GV-386 are Quarterdeck Office Systems' expanded memory manager and DESQview version 1.3 multitasking environment. GV-386 with 40MB hard disk, $3,950; with 80MB hard disk, $4,325.
PC Designs, Inc., 2500 N. Hemlock Circle, Broken Arrow, OK 74012; 918/251-5550

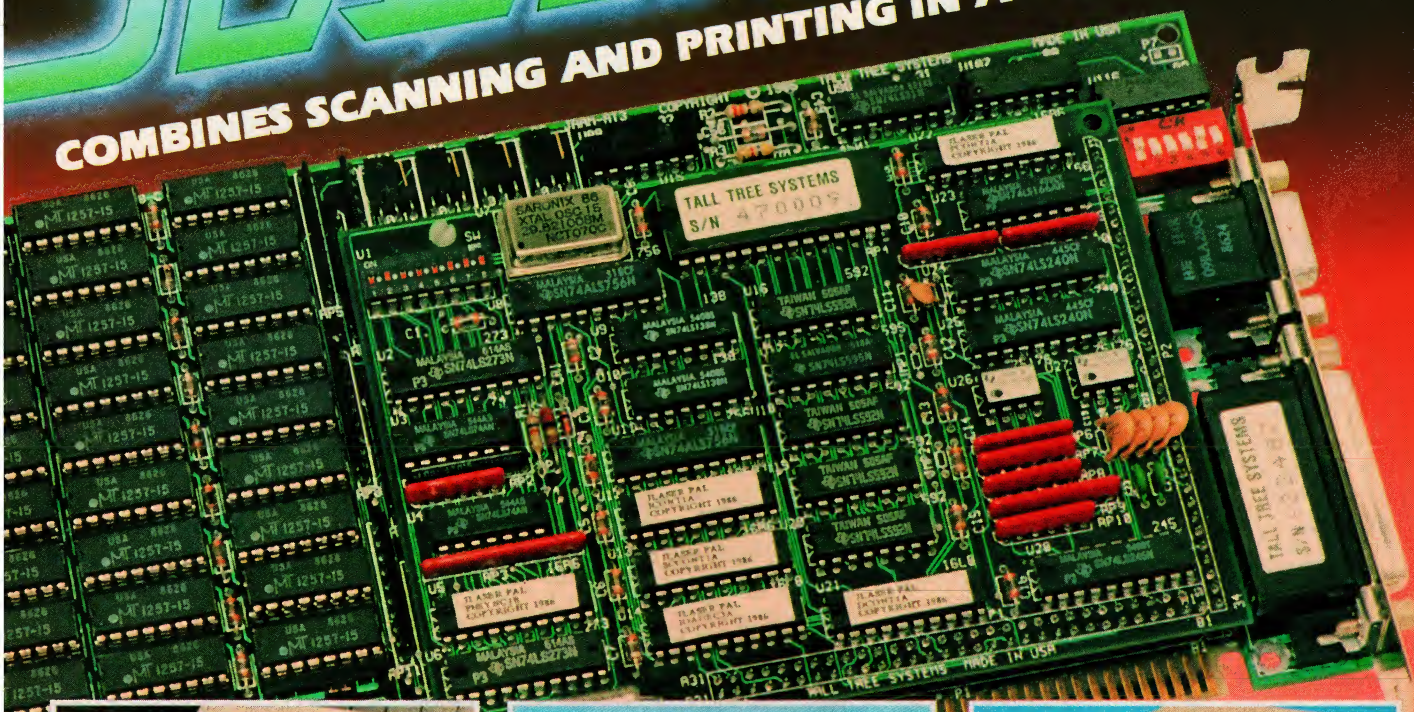
CIRCLE 305 ON READER SERVICE CARD

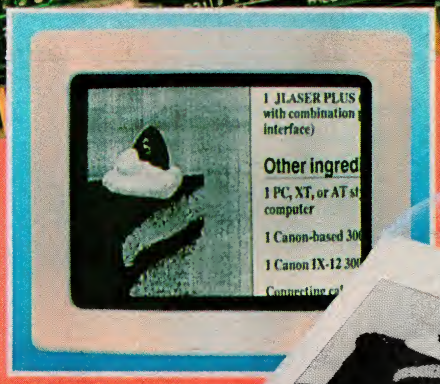
A coprocessor board for the PC bus that contains four 5-MIPS (million instructions per second) NEC μPD7281 data-flow (token-passing) processors is available from **Data Flow Imaging, Inc.** In addition to the four data-flow processors, the **DF-1** board contains an NEC μPD9305 memory access and general bus interface chip and 128KB of local image memory. The μPD7281 processor chip (nicknamed ImPP, for image-pipelined processor) uses a 17-bit-by-17-bit hardware multiplier for high processing speed. A single ImPP can compute a 3-by-3 convolution of a 512-by-512-pixel (8 bits per pixel) image in 2.98 seconds; two ImPPs will do the same convolution in 1.5 seconds. DF-1 supports direct memory access (DMA) transport of data between the PC memory and the DF-1 image memory, and can be configured to use interrupt-driven communications with the PC's CPU. DF-1, $995.
Data Flow Imaging, Inc., P.O. Box 116, Westwood, NJ 07675; 201/666-7970

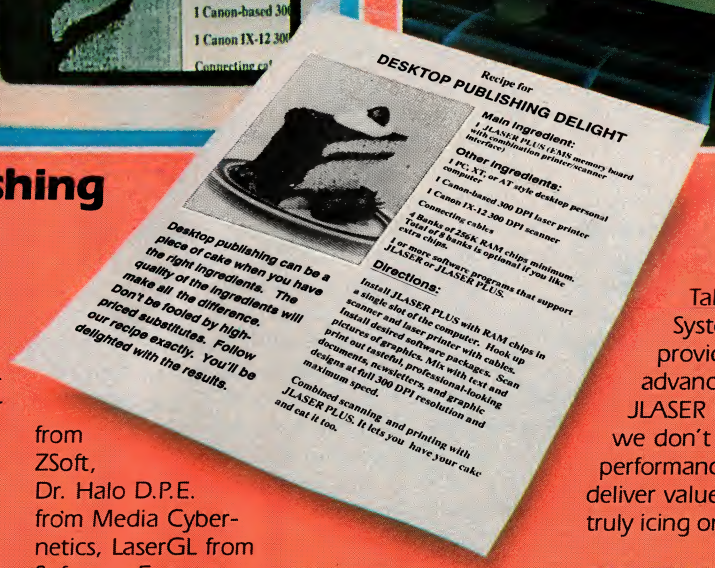
CIRCLE 309 ON READER SERVICE CARD

JLASER PLUS

COMBINES SCANNING AND PRINTING IN A SINGLE BOARD!







It makes desktop publishing a piece of cake!

Tall Tree Systems introduces another breakthrough in desktop publishing with JLASER PLUS. We've combined a 2 MB EMS memory board and an interface to both a Canon®-based laser printer and scanner. JLASER PLUS increases the performance of both devices and gives you a low-cost solution to the limitations you've been experiencing with them.

Furthermore, the same memory that is made available to your printer and scanner is also available for all your other conventional applications. You get system memory, expanded LIM memory, extended memory in an AT-type machine, RAM Disk and print spooler — all in a single slot!

Supporting JLASER PLUS is a host of software packages, such as PC Paintbrush + from ZSoft, Dr. Halo D.P.E. from Media Cybernetics, LaserGL from Software Express, Ventura Publisher from Xerox, Page Builder from White Sciences, Le Print from Le Baugh Software, Fancy Font and Fancy Word from SoftCraft, Inc., and many more to be announced.

It takes a technological innovator like Tall Tree Systems to provide a major advancement like JLASER PLUS. And we don't stop at performance. We also deliver value, which is truly icing on the cake.

TALL TREE SYSTEMS
1120 San Antonio Road
Palo Alto, CA 94303
(415) 964-1980

CIRCLE NO. 194 ON READER SERVICE CARD

TALL TREE SYSTEMS

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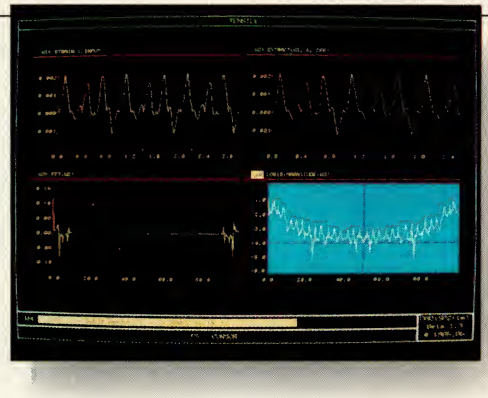
A DOS extender and Command Interpreter from Polytron Corporation



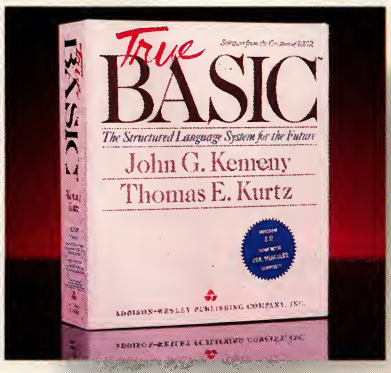
DADiSP Worksheet screen from DSP Systems

SOFTWARE

A DOS extender and command interpreter, **PolyShell**, has been introduced by **Polytron Corporation**. PolyShell adds a UNIX interface to DOS and is invoked as a program under DOS that may be exited or restarted at any time without rebooting. Any DOS command, including internal commands and batch files, can be called from within PolyShell, as can UNIX-like commands. This program includes more than 50 utility programs such as **split**, which splits large files into smaller files; **whereis**, which searches a drive for a particular file; **diff**, which compares two files and prints their differences; and **grep**, which searches files for character strings. $149.
Polytron Corporation, 1815 N.W. 169th Place, Suite 2110, Beaverton, OR 97006; 800/547-4000; in Oregon, 503/645-1150
CIRCLE 334 ON READER SERVICE CARD

Phoenix Technologies, Ltd. has developed a software coprocessor technology that enables manufacturers of computers based on non-IBM-compatible processors, such as the Motorola 68000, to offer a DOS-based, PC-compatible operating mode entirely through software emulation. The **Soft Co-Processor** will provide a fully PC/XT-compatible environment for workstation manufacturers with incompatible operating systems (or processors), and requires no additional hardware. Soft Co-Processor supports all existing I/O controllers. As with hardware coprocessors, Soft Co-Processor traps and responds to all I/O functions with emulation software. However, the soft version includes additional emulation software that remaps the Intel processor instruction set to the host system's native processor. PC video is supported through the standard screen or window manager. The DOS file system is fully integrated with the native file system, thus allowing users to read and write files created from either environment. Licensing to OEMs is available.
Phoenix Technologies, Ltd., 320 Norwood Park South, Norwood, MA 02062; 617/769-7020
CIRCLE 328 ON READER SERVICE CARD

True BASIC, Inc. has released **version 2.0** of **True BASIC**, in which the full range of graphics display cards, including Hercules, IBM EGA, and IBM CGA, is supported; GKI (graphic kernel system) syntax has been expanded; and mouse support added. True BASIC 2.0 features separately compilable modules that may be stored as libraries. Because modules have their own initialization sections, the user can set up global variables, separate graphics output from the rest of the program, or turn on instrumentation. True BASIC 2.0 is faster than earlier versions and offers even better support for 8087/80287 numeric coprocessors. Maximum string length has been increased to 64KB per string, and still supports 640KB of memory. Added debugging tools aid in tracing program execution or printing a cross-referenced listing. $149.90; upgrade, $30.00.
True BASIC, Inc., 39 S. Main Street, Hanover, NH 03755; 603/643-3882
CIRCLE 332 ON READER SERVICE CARD

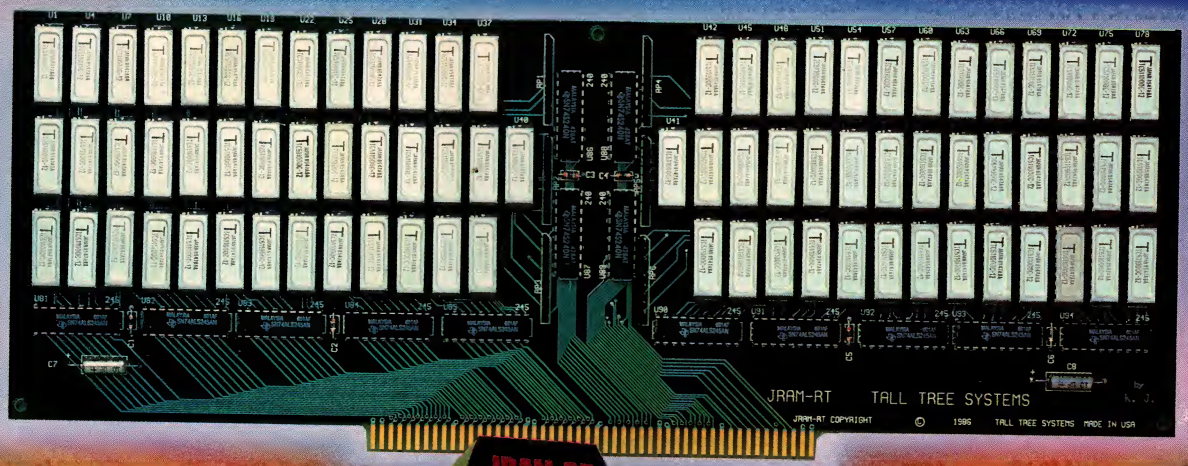


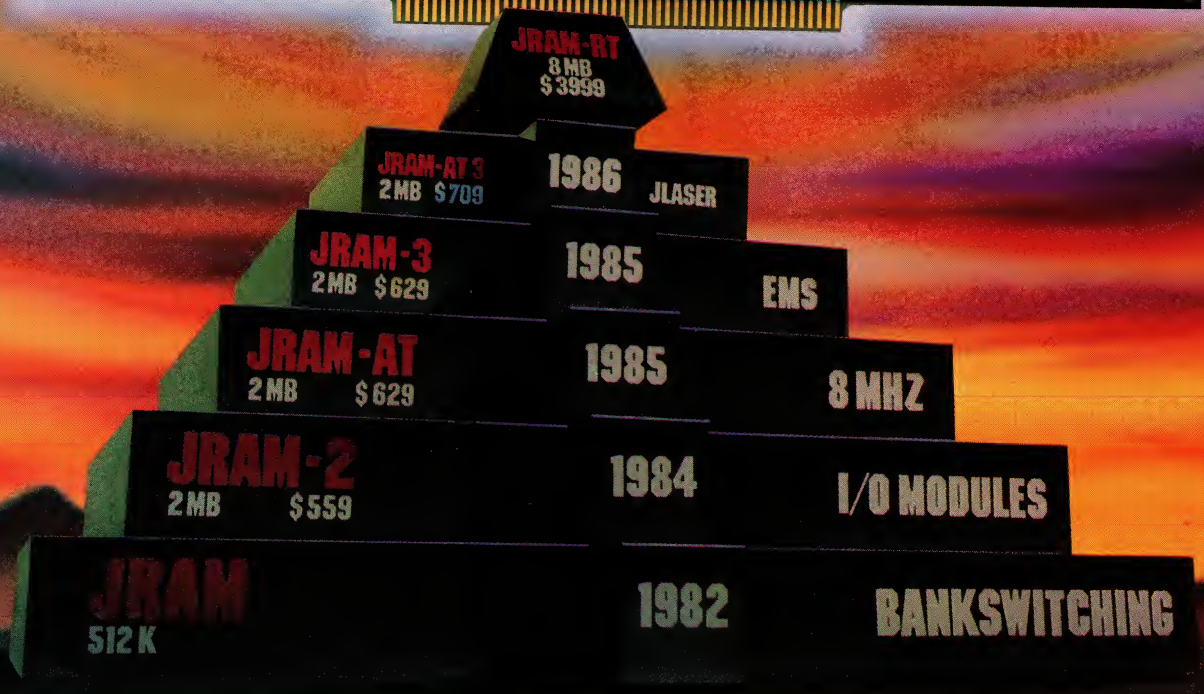
Version 2.0 from True BASIC, Inc.

Version 1.03 of the **DADiSP Worksheet**, a technical spreadsheet for digital signal analysis, is available from **DSP Systems**. DADiSP 1.03 features the **DSP PIPELINE**, which allows users to run external programs within the DADiSP environment. Using DSP PIPELINE, the user can, with a single command, export data from any DADiSP window to an external set of analysis or filtering algorithms and bring the modified data back into DADiSP. He also can run third-party IEEE 488, RS-232, and plotter drivers from DADiSP. $795.
DSP Systems, One Kendall Square, Cambridge, MA 02139; 617/577-1133
CIRCLE 324 ON READER SERVICE CARD

A serial communications product that runs concurrently with DOS and other applications on the PC family is being offered by **Sundance Software, Inc.** **HANDSHAKE** allows users to communicate over serial lines without leaving an application or waiting for the communications to finish before continuing. HANDSHAKE also allows several PCs to be connected to share resources without the need for a file server. Two PC HANDSHAKE links, $229; HANDSHAKE for each additional PC, $99.
Sundance Software, Inc., P.O. Box 434, Redmond, WA 98073; 206/885-0759
CIRCLE 327 ON READER SERVICE CARD

MicroSim Corporation has released **version 3.0** of its **PSpice** analog electrical-circuit simulator. PSpice has been converted from FORTRAN into C in order to make use of the advantages of C: A reduction in the program code size (and more compact data structures) has doubled the maximum circuit size from 120 to 240 metal oxide semiconductors (MOS) transistors on the PC. Execution times have been improved. Changes in input processing allow circuit nodes to be given names or numbers, thus facilitating access nodes inside subcircuits. PSpice 3.0 is compatible with (Univer-





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We have a history of being first.

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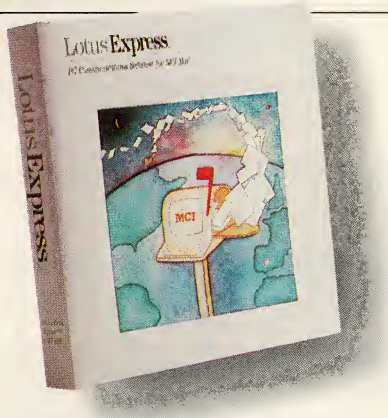
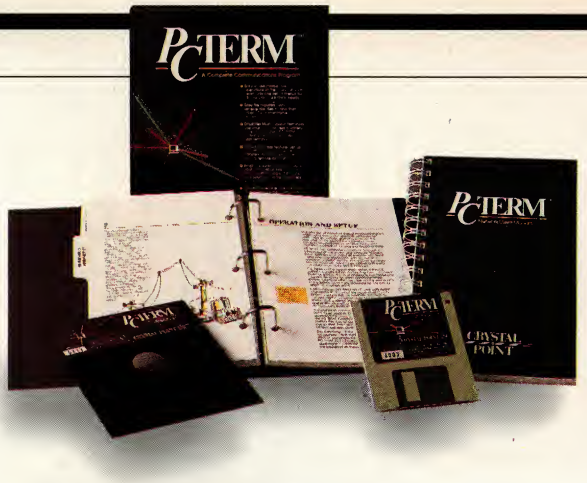


Lotus Express for MCI Mail from Lotus and MCI



PCTERM, a multiterminal emulator from Crystal Point, Inc.

sity of California) Berkeley SPICE2G.6 and includes extensions, such as GaAs MESFET modeling. $950.
MicroSim Corporation, 23175 La Cadena Drive, Laguna Hills, CA 92653; 800/826-8603, in California, 714/770-3022
CIRCLE 326 ON READER SERVICE CARD

Data Access Corporation has announced **FlexTools**, a comprehensive toolkit for developers who use DataFlex, the company's relational database development system. Included with FlexTools are FLEXHELP, a pop-up help utility; FLEXCHANGE, a utility that allows the programmer automatically to change, add, or remove field or index information in DataFlex files; STRIP, a utility that removes all comments and blank lines and left-justifies all lines of source code, which renders the code difficult to read, yet compilable; RELOCATE, a file-management utility; FTXREF, a cross-reference utility; and FTREF2, a source code file search utility. The revamped menu environment lets the user define as many as 24 selections per menu; in addition, the system detects when a menu has more than 12 selections and automatically splits the screen. $195.
Data Access Corporation, 8525 S.W. 129th Terrace, Miami, FL 33156; 305/238-0012
CIRCLE 329 ON READER SERVICE CARD

Lotus Development Corporation and **MCI Communications Corporation** have announced their plans to jointly market **Lotus Express for MCI Mail**, a communications product that makes possible quick and reliable exchange of any binary file. The integrated program gives the user a Lotus interface to the MCI Mail network and its full range of electronic and off-network delivery options, along with on-line help and mail-management facilities. The program lets users compose, read, send, file, archive, and print electronic mail directly from their PCs. Lotus Express can run in the background or as a standalone program. $100.
Lotus Development Corporation, 161 First Street, Cambridge, MA 02142; 617/577-1100
CIRCLE 341 ON READER SERVICE CARD
MCI Communications Corporation, 2000 M Street NW, Suite 300, Washington, DC 20036; 800/624-2255; in Washington, 202/833-8484
CIRCLE 321 ON READER SERVICE CARD

A multiline bulletin board system called **DXL** has been introduced by **Inner Loop Software**. This product supports as many as nine telephone lines in addition to a user at the keyboard. The system operator can customize the system to the application without programming. DXL provides private and public electronic mail, user-to-user mode, and file uploading and downloading using ASCII and XMODEM protocols. System operators can assign up to ten account security levels. Two-line version, $200.
Inner Loop Software, 5456 McConnell Avenue, Suite 120, Los Angeles, CA 90066; 213/822-2800
CIRCLE 322 ON READER SERVICE CARD

PCTERM 3.1, a multiterminal emulator, has been announced by **Crystal Point, Inc.** PCTERM is designed to communicate with a wide spectrum of computers and information services; it currently emulates 15 asynchronous terminals including the IBM 3101. PCTERM can be custom programmed to create unique menu environments; its programming language has more than 80 communications-related commands that allow this product to emulate not only a terminal, but an operator as well, for repetitive data entry. It can be programmed for unattended data transfers with full error-recovery capability and conditional testing based on response. PCTERM also permits unattended remote access to files on the PC, and remote users of PCTERM and other communications packages can upload and download files from an unattended PC. PCTERM is IBM TopView and Microsoft Windows aware; it can be run as a background task permitting remote access. PCTERM also is featured on the Ungermann-Bass Net/One Async PC network (see Hardware). $250.
Crystal Point, Inc., 12221 N.E. 140th Kirkland, WA 98034; 206/821-1909
CIRCLE 336 ON READER SERVICE CARD

Dasoft Design Systems, Inc. has announced a CAD package for engineers. **Project: PCB** provides complete schematic capture, board layout, and autorouting capabilities. Graphics options include Hercules monochrome, IBM CGA, and IBM EGA with monochrome or color monitor. A system mouse is required, and a wide variety of plotters is supported. Special features include user-definable schematic and silk-screen symbols; user-definable footprints to 1/100-inch accuracy; block move, copy, and delete functions; screen display of unrouted traces on the board; a tag-and-drag function in interactive routing mode; four-layer boards (two signal layers, plus internal planes); single-net or full-board autorouting; routines for producing net lists, parts lists, and hole lists; plot routines for camera-ready artwork; and optional predefined libraries of parts and symbols. $950.
Dasoft Design Systems, Inc., P.O. Box 8088, Berkeley, CA 94707-8088; 415/486-0856
CIRCLE 323 ON READER SERVICE CARD

Command Plus version 1.1 has been announced by **ESP Software Systems, Inc.** Created as a programming environment for DOS, Command Plus features an aliasing command, which allows the user to create fast, memory-resident command macros; a history command, which lets the user edit and execute commands that were run as many as 48 command lines before; disk-manage-

A Challenge to Microsoft® C...

We challenge Microsoft C (Ver 4.0) to a C compiler duel to the finish, measuring compile, link, and execution times. If they win, we will stop advertising for two months.

by Roy Sherrill

If Microsoft C (Ver 4.0) can beat Optimum-C then we will stop advertising in all magazines for two full months and, win or lose, we will publish the results in its entirety. Even the Microsoft ads say "The Fastest C you've ever seen," so let the challenge begin.

Walter says Optimum-C is better

It all started when Walter Bright, the developer of Optimum-C, was explaining his new global optimizing C compiler and how it's code would be faster than Microsoft C (Ver. 4.0). Walter and I were frustrated because here we had a C compiler that would beat Microsoft C on 7 out of 10 benchmarks and also compile and link faster; yet our marketing consultant, Mark Astengo, told us that Microsoft C had a lock on the C compiler market and by 1990 they would probably have an 80% market share. Then Mark said, "Roy, if your C compiler is as fast as you say it is, why not challenge Microsoft C to a duel? If Microsoft wins, Datalight should stop advertising for two months and print the results of the test, win or lose." Well, I've always been one for a challenge. So here it is...

We only ask the following...

The benchmark suite will consist of the set of programs that Microsoft supplied to *Computer Language* for their February 1987 C compiler review issue. Microsoft will make available the programs to Datalight at least two weeks prior to the benchmarking. The benchmarking will be between Microsoft C 4.0 and Optimum-C. It will occur at a mutually agreed upon time and place. Interested individuals will be allowed to attend. The benchmarks will be compiled and run on a standard IBM PC-AT.

There will be two separate tests for each program: compile and link speed, and execution speed. For each test, a representative from each company will set up the compiler so that it performs at its best.

The benchmarks will be adjusted so that they take sufficiently long to run, that the tolerance involved in timing them is insignificant. The winner is determined by the compiler with the faster execution times for the majority ofthe benchmarks. We'd like an answer from Microsoft no later than April 1, 1987.

So what's a global optimizer?

A global optimizer looks at an entire function at once, analyzing and optimizing the whole function. A technique called data flow analysis is used by Optimum-C to gather information about each function. This enables your compute-bound programs to execute as much as 30% faster after global optimization. But, there is one catch...because the global optimizer ruthlessly searches for ways to speed-up execution speed and minimize memory usage, it has relatively slow compile times. No need to worry, though, because you can merely turn the global optimizer off. In fact, you can select all, none, or partial of the following optimizations: constant propagation, copy propagation, dead assignment elimination, dead variable elimination, dead code elimination, do register optimizations, global common subexpression elimination, loop invariant removal, loop induction variables, optimize for space, optimize for time, very busy expressions.

Choose from five memory models

Speed your programs by selecting the memory model that best suits your application.

Memory Models

Model	Code	Data
Compact	64k total code & data	
Small	64k	64k
Program	1M	64k
Data	64k	1M
Large	1M	1M

Compiling, one step...

Now with the one step DLC program you can create .OBJ, .EXE and .COM files. Also, DLC can handle multiple files and run MASM on your assembly files.

Try Optimum-C risk free

Try Optimum-C for 30 days and if you are not 100% satisfied return it for a full refund. Also, for a limited time we are including a *free C tutorial which is a combination workbook and floppy disk to help lead you through the C language with tutorials, quizzes, and program exercises.

O.K. Microsoft, it's up to you. We've put two months of advertising on the line that says you can't beat Optimum-C to a real test. Your answer, please?

PRICES

Developer's Kit	still only $99
Optimum-C (includes library source code)	$139

Add $5 for shipping in US/$15 outside US
COD (add $2.50)

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Magazine Reviewers Shocked by DATALIGHT's Performance...

"Reviewing this compiler was quite a surprise for us. For such a low price, we were expecting a "lightweight" compiler. What we got was a package that is as good as or better than most of the "heavyweights." Datalight C implements a complete C language. It also compiles quickly, doesn't take up much disk space, and looks impressive in the benchmarks."

***DR. DOBBS*, August 1986**

"This is a sharp compiler!... what is impressive is that Datalight not only stole the compile time show completely, but had the fastest Fibonacci executable time and had excellent object file sizes to boot!"

***COMPUTER LANGUAGE*, February 1986**

Optimum-C Version 3.0

- Full UNIX System 5 C language plus ANSI extensions
- Fast/tight code via powerful optimizations including common sub-expression elimination
- DLC one-step compile/link program
- Multiple memory model support
- UNIX compatible library with PC functions
- Compatible with DOS linker and assembler
- Third-party library support
- Automatic generation of .COM files
- Supports DOS pathnames, wild cards, and Input/Output redirection
- Compatible with Lattice C version 2.x
- Interrupt handling in C
- Debugger support
- ROMable code support/start-up source

MS-DOS® Support Features

- Mouse support
- Sound support
- Fast screen I/O
- Interrupt handler

MAKE Maintenance Utility

- Macro definition support
- MS-DOS internal commands
- Inference rule support
- TOUCH date manager

Tools in Source Code

- cat—UNIX style "type"
- diff—Text file differences
- fgrep—fast text search
- pr—Page printer
- pwd—Print working directory
- wc—Word count

Datalight

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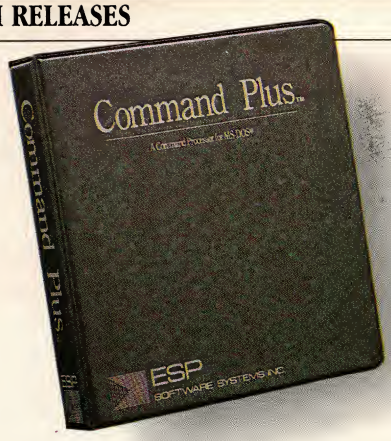
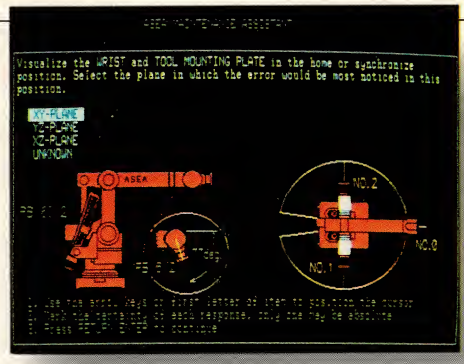
Kenmore, Washington 98028
(206) 367-1803

*Limited offer available exclusively to readers who purchase directly from Datalight.

CIRCLE NO. 107 ON READER SERVICE CARD



Command Plus programming environment from ESP Software Systems



Screen from Personal Consultant Plus (PC Plus) from Texas Instruments

ment utilities, which contain options to process subdirectories recursively, sort files, and specify multiple source files; BROWSE, a full-screen file viewer with regular expression searching and IBM EGA 43-line support; command line editing with user-definable editing keys; and the ability to create multiple commands and arguments on a line. $79.95.
ESP Software Systems, Inc., 11965 Venice Blvd., Suite 309, Los Angeles, CA 90066; 800/992-4377; in California, 213/390-7408

CIRCLE 325 ON READER SERVICE CARD

A BASIC programmer's package has been introduced by **MicroHelp, Inc.** **Sta-Res** makes compiled BASIC programs memory-resident, such that they can be invoked by pressing a selectable hot key. For machines that use DOS 3.0 or later plus an expanded/extended memory board, adding the EMS/RAM disk module ensures that each memory-resident program takes only 7KB of DOS memory, and the balance of the program is swapped in and out of memory as needed. Included in the program is a SHELL facility that allows the user to execute any program, even other BASIC programs and the BASIC interpreter. Sta-Res is not copy protected, and no royalties are imposed when Sta-Res-assisted programs are distributed as a part of executable programs. $95; EMS/RAM disk module, $50.
MicroHelp, Inc., 2220 Carlyle Drive, Marietta, GA 30062; 404/973-9272

CIRCLE 339 ON READER SERVICE CARD

Big Bang Software, Inc. has released an **MC68000/68010 Simulator/Debugger** for the PC. The package enables the user to test and debug 68000/10 software on the PC; hexadecimal files of Motorola S-Records can be disassembled and displayed. Instructions can be executed in fast or single-step mode, and the results of each executed instruction on registers, flags, and 68000/10 memory are immediately available for display. During single-stepping, the display shows the last instruction executed, the current contents of all registers, and the instruction following the last executed. All 68000/10 instructions, addressing modes, and condition codes are fully supported. Load, dump, and breakpoint facilities are included. $285.
Big Bang Software, Inc., P.O. Box 879, Panama City, FL 32402; 904/784-3393

CIRCLE 333 ON READER SERVICE CARD

The **Personal Consultant Series**, a family of expert system development tools is being offered by **Texas Instruments** (TI). **Personal Consultant Easy** is designed for users just beginning in expert system development, and it features high functionality for rapid prototyping of small- to medium-sized expert system applications. **Personal Consultant Plus** (PC Plus), a more powerful member, is designed to take

Screen from TI's Personal Consultant Easy

advantage of PC/AT-class machines. PC Plus provides extended knowledge-representation features, increased rule capacity, and access to LISP, thus providing sophisticated developers the flexibility to customize their applications. Knowledge bases created with Personal Consultant Easy are upwardly compatible with PC Plus. Applications developed under either product can be delivered on microcomputers with the addition of an optional runtime diskette. Personal Consultant Easy, $495; PC Plus, $2,950; demo diskette, $25; runtime diskettes, $95 each or $995 for 20, PC Scheme (TI's LISP compiler), $95.
Texas Instruments, Data Systems Group, AI Software Marketing Department, M/S 2244, P.O. Box 2909, Austin, TX 78769-2909; 800/527-3500

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MicroCICS will interpret and execute applications according to the features supported by the CICS release that the programmer selects. It allows development of command-level CICS COBOL and assembly language source programs outside the mainframe environment. MicroCICS includes on-line screen generation and automatic creation of basic mapping support (BMS) maps, creation and maintenance of test data files, program execution and testing using a powerful symbolic debugger, and host communications for program uploading and downloading. PC-370, $4,495.
Unicorn Systems Company, 3807 Wilshire Blvd., Los Angeles, CA 90010; 213/380-6974

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apl language

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basic language

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cobol language

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forth language

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other languages

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Informix4GL *for DOS by Informix*	995	789
InformixSQL *for DOS by Informix*	795	639
Instant Replay *by Nostradamus*	90	79
Interactive EASYFLOW *by Haventree*	150	129
MKS Toolkit *with vi by MKS*	139	119
Norton Commander *by Peter Norton*	75	55
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OPT-Tech Sort *by Opt-Tech Data Proc*	149	115
PrintQ *by Software Directions*	89	84
Quilt Computing Combo Package	199	159
QMake *Program Rebuild Utility*	99	84
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Pfix-86 Plus *Symbolic Debugger*	395	229
PforCe *Comprehensive C Library*	395	229
Plink-86 Plus *Overlay Linker*	495	319
Pmaker *Make Utility*	125	78
Pmate *Macro Text Editor*	195	115
Pre-C *Lint Utility*	295	155
Ptel *Binary File Transfer Program*	195	115

polytron products

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KEDIT *by Mansfield Software*	125	99
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ALICE *Interpreter by Software Channels*	95	66
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TurboRef *by Gracon Services*	50	45
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xenix system v

See also Microport System V/AT section.

XENIX System V Complete *by SCO*	1295	999
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xenix products

Btrieve *ISAM File Mgr by SoftCraft*	595	464
C-ISAM *by Informix*	319	285
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c-tree *ISAM Mgr by FairCom*	395	329
dbVISTA *All Varieties by Raima*	CALL	CALL
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DOSIX *User Version by Data Basics*	199	CALL
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Informix *by Informix*	995	795
Informix4GL *by Informix*	1500	1239
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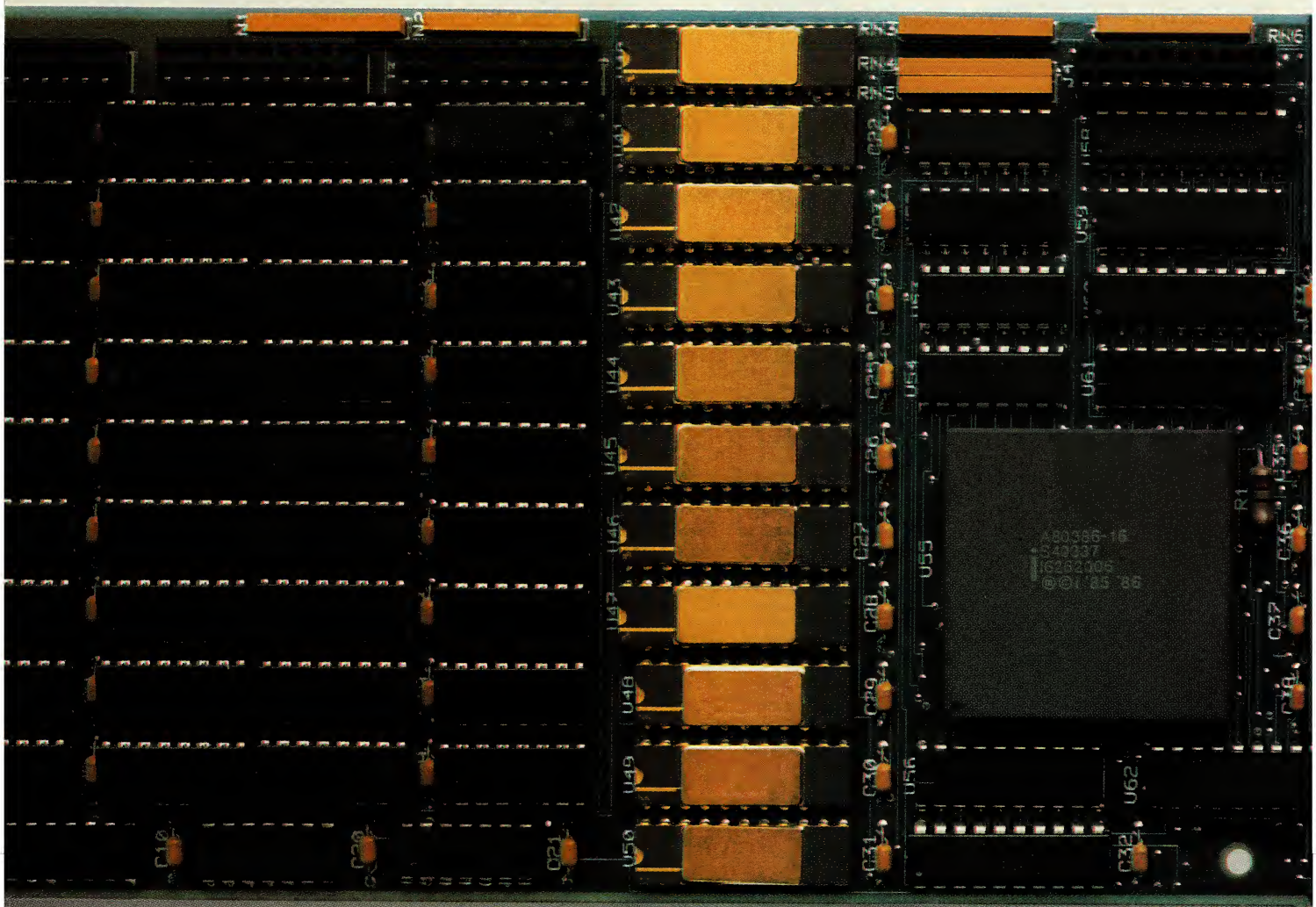
programmer's connection

How to 386



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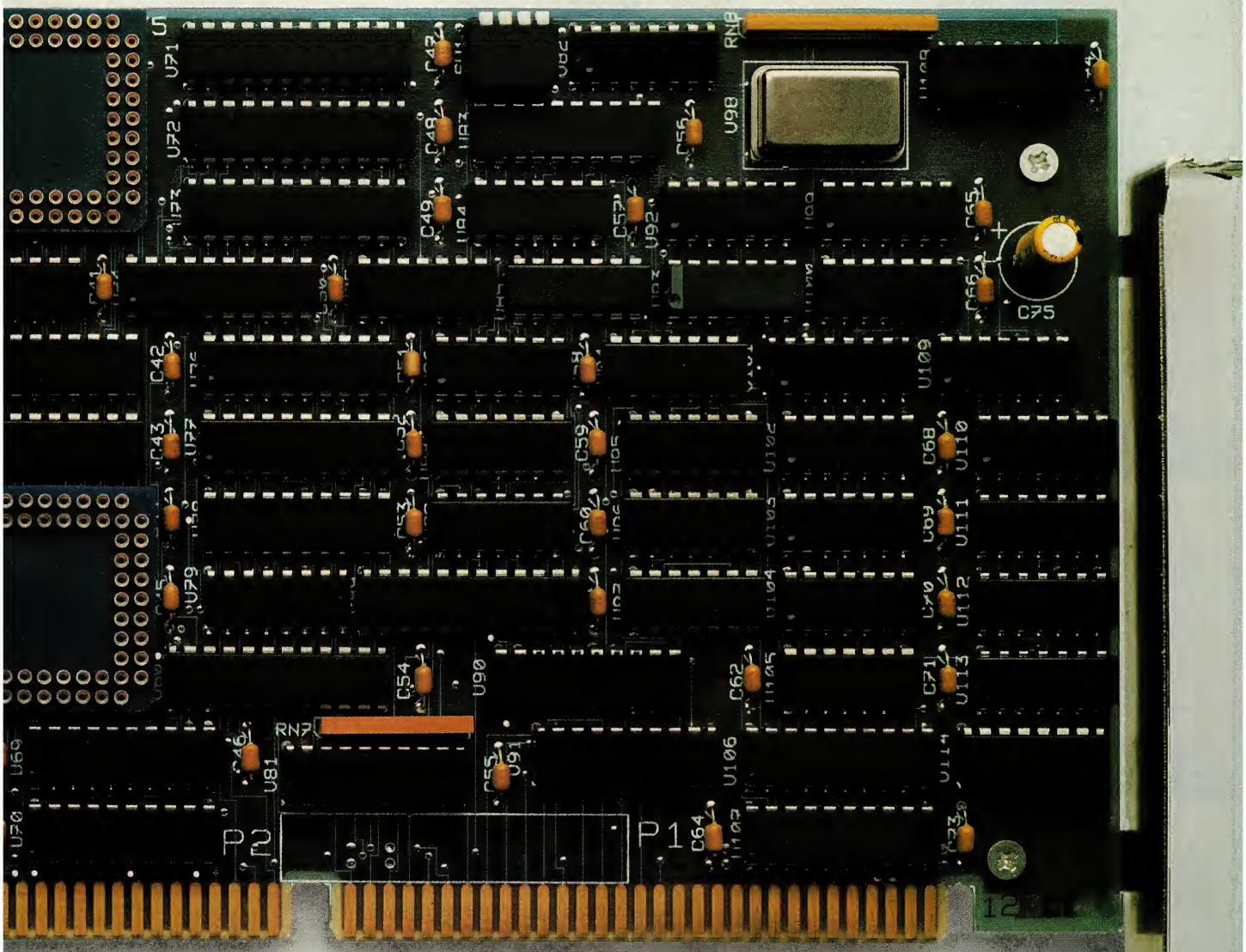

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TECH NOTEBOOK 74

DEAN P. GIENGER

XON/XOFF Printer Driver

By using the XON/XOFF software handshaking method shown here, the PC can support peripherals that have serial interfaces.

Although the IBM PC supports parallel printers with ease, there are times when driving serial peripherals would be desirable. Many popular printers, such as the Hewlett-Packard LaserJet, use serial (or RS-232) interfaces.

Because most printers can print characters at only a fraction of the rate that a PC can send them, a printer must exchange some *handshaking*, or control signals, to control the rate at which characters are sent by the PC. This control can be done through either hardware or software.

The hardware method involves connecting a special wire between the printer and the PC. When the printer is ready to accept data, it asserts a logic 1 on this wire. When the printer is unable to accept data, it asserts a logic 0. The PC must then check the status of this signal before sending data. This simple method of flow control has several drawbacks. First, it requires an additional wire in the interface cable. Second, the printer cannot return any additional status data (paper out, device off-line, and so on) unless additional wires are connected between the PC and the printer.

The software method involves having the printer send special flow control characters to the PC to notify it of status conditions. When the printer is able to accept data it will send a special character, called an XON character—chr(17). When the printer is unable to accept data, an XOFF character—chr(19)—is sent by the printer to the PC. Other characters may be sent to notify the PC of special conditions.

The PC may be configured with either serial or parallel ports; however, the PC's software drivers support only the hardware method of handshaking. The program below provides a software driver that allows the PC to use a serial printer that uses XON/XOFF software handshaking.

The program "steals" the special BIOS printer interrupt vector reserved for printer functions. This vector is located in low memory at address 0000:005CH and is normally set to point to the printer driver code located in the system ROM. The program redirects this vector to point to its own code for driving the serial port using XON/XOFF handshaking. Once the XON program is loaded, it directs all printer output to the serial port. A serial printer then can be used as if it is a standard parallel interface printer.

Dean P. Gienger is an engineering consultant in California.

LISTING 1: XON.ASM

```
; Use DOS MODE to redirect LPT1: to COM1: and set up the BAUD rate etc
rom_ptr_vec     equ     17h*4           ; rom vector location
com             equ     03f8h           ; com1=3f8, com2=2f8
code            segment public  'CODE'
                assume  cs:code,ds:code
                org     0100h
start           proc    far             ; patch in the new code
                cli                     ; disable interrupts
                sub     ax,ax           ; set es segment
                mov     es,ax           ; copy vector
                mov     ax,cs           ; reset ptr_vector
                mov     es:word ptr[rom_ptr_vec+2],ax
                mov     ax,offset ptr_int
                mov     es:word ptr[rom_ptr_vec],ax
                sti                     ; reenable interrupts
                mov     dx,offset last_byte  ; call dos to exit
                int     27h             ; and stay resident
                db      '(c) 1986, Dean P Gienger'
start           endp
ptrint          proc    far             ; we get here from int 17h
ptr_int:        sti                     ; enable interrupts
                cmp     ah,0            ; is this an output req?
                je      ptr_out         ; yes
                cmp     ah,1            ; is it an init req?
                je      ptr_init        ; yes
ptr_stat:       push    dx              ; it must be a status req
                mov     dx,com+5        ; get status
                in      al,dx
                and     al,20h
                je      ptr_busy        ; port is busy
                mov     dx,com
                in      al,dx           ; is there an xoff ?
                and     al,7fh
                cmp     al,19           ; xoff is ^S ( 19 )
                je      ptr_busy        ; yes, it is busy
                mov     ah,80h          ; else return not busy
                pop     dx
                iret
ptr_busy:       mov     ah,00h          ; return busy status
                pop     dx
                iret
ptr_out:        push    ax              ; print character & save
ptr_wait:       mov     ah,2            ; wait till printer free
                int     17h             ; ready?
                and     ah,80h
                jz      ptr_wait        ; no
                pop     ax              ; yes, get char from stk
                push    dx
                mov     dx,com          ; send character
                out     dx,al
                pop     dx
                mov     ah,2            ; return status
                int     17h
                iret
ptr_init:       mov     ax,27           ; initialize the printer
                int     17h             ; send ESC E
                mov     ax,45h          ; to init printer
                int     17h
                mov     ah,2            ; return status
                int     17h
                iret
last_byte:
ptrint          endp
                code    ends
                end
```

COMPATIBILITY 386 PERFORMANCE

COMPAQ DESKPRO 386

The New Standard

Compaq has forged ahead of IBM with the first 80386-based machine, offering AT compatibility with twice the performance—and a bright future in multitasking.

STEVEN ARMBRUST and TED FORGERON

Until now, Compaq Computer Corporation has been content with matching IBM's personal computer offerings, merely making minor improvements to what IBM already had created. With the introduction of the Deskpro 386, however, Compaq has leapfrogged over IBM into brand new territory. Powered by a 16-MHz Intel 80386 microprocessor and equipped with 32-bit memory and a speedy hard-disk drive, the Deskpro 386 not only offers compatibility with IBM's PC/AT at twice the performance, but also promises to run future multitasking operating environments that will take advantage of the 80386 processor.

The Deskpro 386 comes in three models, distinguished only by the hard disk. The model 40 is equipped with a 40MB hard disk, the model 70 with a 70MB hard disk, and the model 130 with a 130MB hard disk. The monitor, the amount of memory, and the keyboard are options that can be selected with each model. The accompanying sidebar lists the features available with the Deskpro 386. The unit reviewed in this article was the model 40 with 1MB of RAM, a 1.2MB diskette drive, a 360KB diskette drive, a 40MB tape backup unit, a serial and a parallel port, the Compaq Enhanced Color Graphics Board, and the Compaq Color Monitor.

At first glance, the Deskpro 386 looks just like the other members of the Deskpro family. It uses the same cabinet as the Deskpro 286 and therefore has many of the same advantages and disadvantages as that unit has (see "Out from the Shadow of IBM: Compaq Deskpro 286," Steven Armbrust and Ted Forgeron, August, 1986, p. 80). The size of the system unit is 19¾ inches by 16½ inches by 6¼ inches. Photo 1 compares its footprint with that of an AT.

Like the Deskpro 286, the Deskpro 386 includes the same unattractive key-lock switch on the front of the system unit, with barely readable switch positions. It also has the on/off switch posi-

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PHOTO 1: *System Unit Footprint*

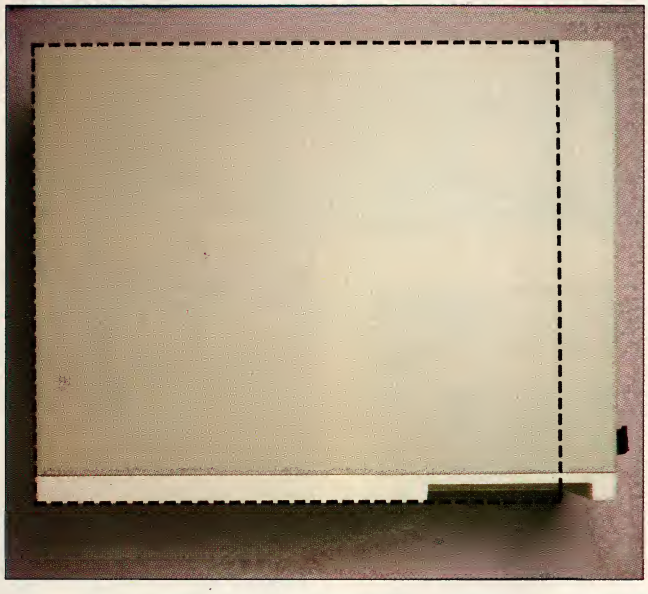


PHOTO 2: *Keyboard Comparison*

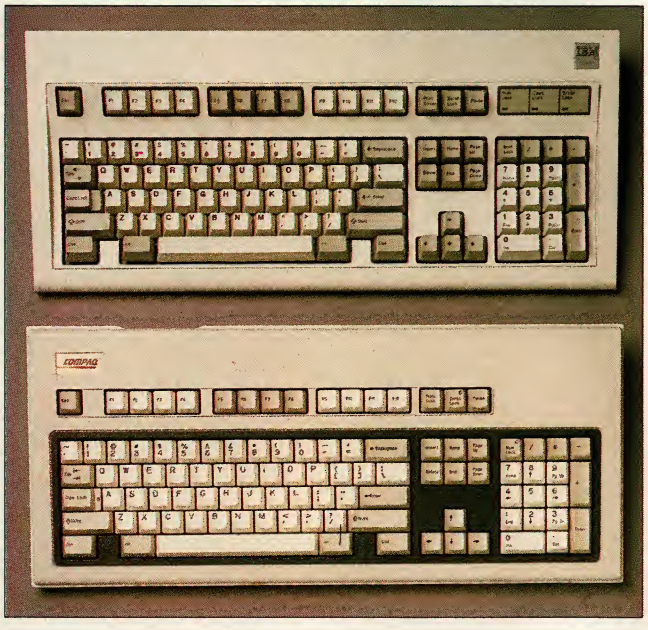


PHOTO 3: *Compaq Color Monitor*

PHOTO 4: *Inside the System Unit*

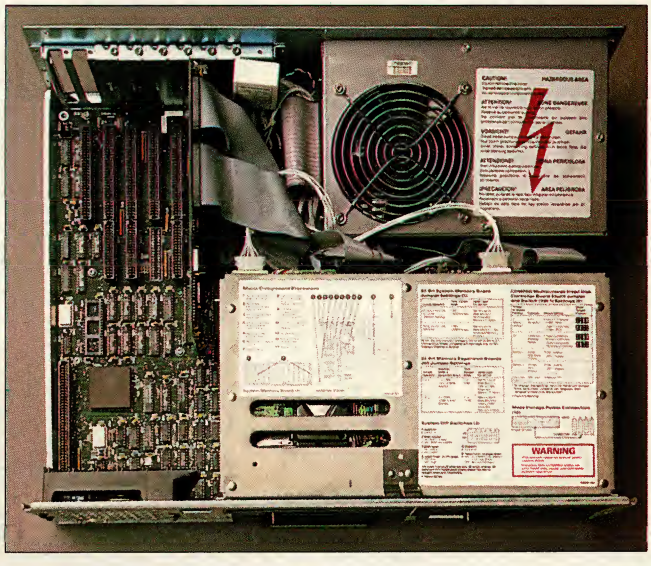


PHOTO 5: *System Memory Board*

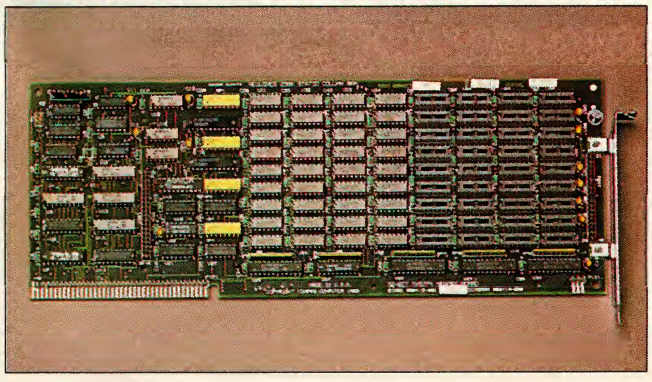


Photo 1: The system unit of the Deskpro 386 is smaller than the IBM AT. The Deskpro measures 19¾ by 16½ by 6¼ inches, as indicated by the dotted lines.

Photo 2: The layout of the enhanced keyboard of the Deskpro 386 matches that of the IBM enhanced keyboard in most respects, but does not have the same IBM feel.

Photo 3: Screen controls and the power switch are located on the side of the monitor. The monitor may be tilted up 5 or 10 degrees using the built-in tilt bar.

Photo 4: Slot 1, the leftmost slot, is the 32-bit slot. The main connector for this slot is at the front of the system unit. A small power/ground connector is located near the rear.

Photo 5: The main 32-bit connector is on the bottom left of the board. The two double rows of pins protruding from the board are for attaching a piggyback memory module.

tioned on the rear panel of the unit where it is difficult to find. The two machines share the convenient feature of a two-color drive light that shines green when accessing a 1.2MB diskette and red when accessing a 360KB diskette.

Two keyboards are available for the Deskpro 386: one matching the layout of IBM's original AT keyboard and one matching IBM's enhanced keyboard. The only difference between the new Compaq keyboard and the earlier one is in the layout. The keys still have a light touch and provide little tactile feedback. The keyboard plugs into the front of the system unit, requiring its removal whenever the cover of the system unit is taken off. As with other Deskpro models, the keyboard cable seems to be excessively long, but this problem can be alleviated by tilting up the keyboard on its legs and placing the excess cable underneath. Photo 2 compares Compaq's enhanced keyboard with that of IBM.

With the Deskpro 386, Compaq offers its new Color Monitor and Enhanced Graphics Board, which is compatible with the IBM Enhanced Graphics Adapter (EGA). The Compaq Color Monitor is compatible with IBM's Enhanced Color Display. It produces accurate colors and text that is easy to read. However, when compared to the new generation of enhanced color monitors, such as the NEC Multisync, the characters produced by the Compaq monitor in high-resolution text mode are not as crisp and clear. The monitor controls are conveniently placed on the side of the display where they can be accessed easily (see photo 3).

The Compaq graphics board works with both the color display and Compaq's dual-mode monochrome display. When connected to the dual-mode monochrome display and switched into monochrome emulation mode, the Compaq graphics board can produce text with a resolution of 720-by-350 pixels. When connected to the Compaq Color Monitor (or another enhanced color display), it offers 16 colors from a palette of 64 and a resolution of 640-by-350 pixels. The graphics board also can be used with an ordinary color display to generate output equivalent to that produced by IBM's Color Graphics Adapter (CGA). However, it cannot be connected to an IBM monochrome monitor (or the equivalent) without damaging the display. The board can be installed in other Compaq computers, such as the Portable or Portable II, where it can drive either the built-in dual-mode display or a color display.

80386 ENHANCEMENT

The Deskpro 386 is loaded with extras that are not available on any other AT-compatible computer, but by far the most exciting and obvious of these is the 80386. This 32-bit microprocessor from Intel has 32-bit instruction and data paths, provides real and protected modes, and offers a virtual-8086 mode and memory paging that enable it to handle multiple real-mode applications (such as DOS applications) simultaneously. (For a complete description of the capabilities of the 80386, see "Upward to the 80386," Caldwell Crosswy and Mike Perez, February 1987, p. 50.)

The Deskpro 386 system starts running with the 80386 in real mode, and a reboot always returns the processor to this mode. When operating in real mode, all the restrictions associated with 8086/88 processors apply. Segments are limited to 64KB, and the memory address space is 1MB. The 80386's 32-bit instructions can be used, however, enabling programs to improve performance with 32-bit data transfers and 32-bit operands for instructions.

Protected mode in the Deskpro 386 is compatible with the protected mode in 80286 machines, but the 80386 increases the memory address space (from 16MB to 4GB) and the maximum segment size (from 64KB to 4GB). In addition, it also provides memory paging, I/O protection, a full 32-bit instruction set, and virtual-8086 mode.

Virtual-8086 mode is a special form of protected mode that enables real-mode applications to execute within protected mode. In virtual-8086 mode, memory addressing reverts to the base:offset form used in the 8088 and in real mode on the 80286 and 80386. This permits current application programs to run, but confines them to the 1MB address space of the 8088. Despite this limitation, the paging facilities (described below) of the 80386 permit the 1MB real-mode address space to be mapped anywhere in the 4GB address space that is available in protected mode, thus permitting several real-mode applications to run concurrently—without any modification.

The Deskpro 386 uses this virtual-8086 mode and memory paging combination to implement its own Compaq Expanded Memory Manager (CEMM). This program gives DOS applications access to the expanded memory outlined in the Lotus-Intel-Microsoft (LIM) specification without requiring special bank-switching memory boards.

In the Deskpro 386, the 80386 processor runs at 16 MHz, twice the speed at which the 80286 runs in the AT. In addition, the 80386 can access RAM 32 bits at a time (compared with the 16-bit memory access provided by the 80286). With this double dose of supercharging, DOS applications might be expected to run four times as fast as they do on an 8-MHz AT; however, because the cur-

DESKPRO 386 VITAL STATISTICS

Model 40: $6,499
1MB memory
Parallel printer interface
Serial interface
1.2MB diskette drive
Realtime clock
40MB hard disk

Model 70: $7,299
All features of Model 40 except with a 70MB hard disk.

Model 130: $8,799
All features of Model 40 except with a 130MB hard disk.

Display adapters (none is standard)
Dual-mode
Enhanced Color Graphics Board

Monitors (none is standard)
Dual-mode monochrome monitor
Enhanced color monitor

Memory capacity on system board
None

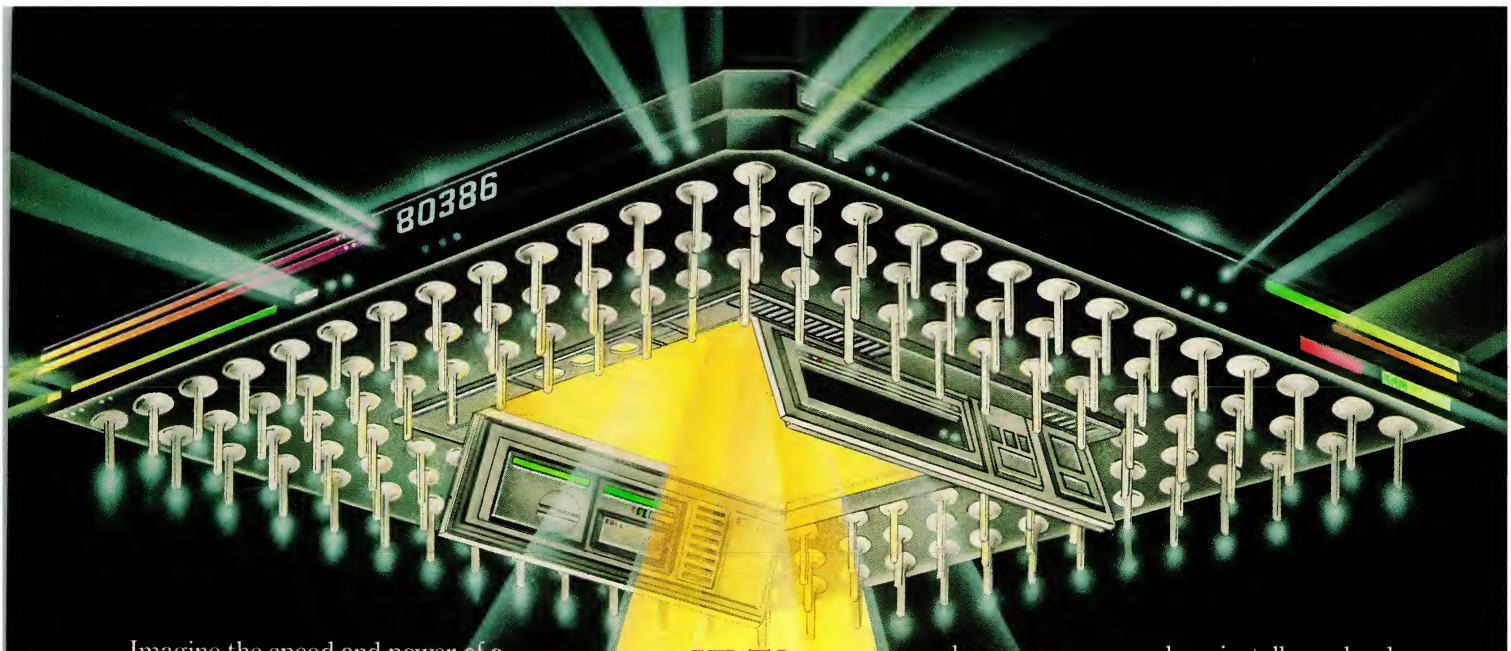
32-bit memory capacity of system
10MB

Expansion slots
32-bit: 1
16-bit: 4
8-bit: 3 (one half-size slot)

Available slots

Model 40		Model 130	
32-bit:	0	32-bit:	0
16-bit:	3	16-bit:	2
8-bit:	2	8-bit:	2

Other extras available
40MB tape backup: $799
360KB diskette drive: $225
1MB memory option: $549
1MB/2MB expansion board: $849
4MB/8MB expansion board: $2,995



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CIRCLE NO. 196 ON READER SERVICE CARD

rent versions of DOS and the applications that run under them are written for 16-bit processors, code and data are still accessed 16 bits, rather than 32, at a time. Despite this underutilization of the 80386, existing real-mode programs run approximately twice as fast on the Deskpro 386 as on an 8-MHz AT.

In the future, programs that take advantage of the 32-bit instruction set of the 80386 can expect to improve performance even more. For example, the 32-bit version of the MOV instruction, which is available even in real mode, can potentially double the data-transfer speed provided by the 80286.

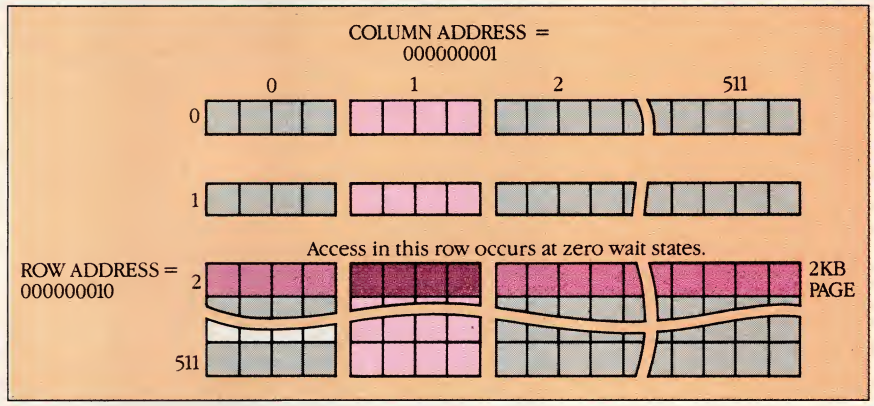
To take advantage of the 32-bit data path of the 80386, the Deskpro 386 provides a 32-bit memory bus for access to RAM. This bus takes the form of a 32-bit slot on the system board. Compaq claims that this is not a general-purpose bus, but merely a mechanism to optimize the performance of the Deskpro 386 memory subsystem. It enforces this opinion by providing just a single 32-bit slot and by not supplying any RAM on the system board itself. A 32-bit memory board, supplied in the standard configuration with 1MB of soldered RAM, fits into this slot. With additional 256K-by-1 static-column DRAM chips, this board can be expanded to 2MB. One of two piggyback boards can be added to the 32-bit memory board: one provides 1MB, expandable to 2MB, with 256K-by-1 chips; the other provides 4MB, expandable to 8MB, with 1M-by-1 chips. Thus, the Deskpro 386 can contain as much as 10MB of RAM, all accessed via the single 32-bit slot.

The 32-bit slot consists of an 80-pin connector whose signals are generated directly by the 80386. This memory bus, which runs at 16 MHz, is simply an extension of the processor's local bus. This direct interface minimizes the signal delays between the processor and the memory subsystem.

The 32-bit memory boards are configured into a 36-bit wide arrangement, consisting of 32 bits of data and 4 bits of parity (one parity bit for each byte). On the system memory board, and on the 1MB/2MB piggyback board, the memory chips are 256K-by-1 static-column DRAMs, yielding a memory bank size of 256K 32-bit double words, or 1MB. On the 4MB/8MB piggyback board, the memory chips are 1M-by-1 DRAMs, yielding memory banks of 4MB.

With a 16-MHz processor, fast access to RAM is essential; otherwise, the speed advantages of the processor are negated. In the PC, the cycle time of the 8088 is 210 nanoseconds (ns), and a bus cycle is 840 ns, enabling readily available 200-ns DRAM chips to be used. The 200 ns is the access time, or the time required for a charged DRAM to return information. Additional time is required to recharge the DRAM for the next memory access. The sum of the access time and the recharge time is the DRAM cycle time, which is the actual time needed to obtain information from the chip. In 200-ns DRAM chips, the cycle time is 345 ns.

FIGURE 1: *RAS/CAS Memory Access*



To access memory in each 1MB bank, the memory subsystem specifies nine-bit row and column addresses. Static-column RAM allows the memory to respond in zero wait states if the row address is the same as in the previous memory access.

The cycle time of a 16-MHz 80386 is 62.5 ns. Using 200-ns RAM chips and an ordinary memory-accessing scheme would reduce the overall performance to little better than that of a PC, because wait states would have to be inserted to make the processor spend some of its time waiting for memory.

The easiest way to improve memory access times is to remove all wait states and use faster DRAM chips. However, to make significant improvements, chips with memory access times in the 60-ns range are required, and those are prohibitively expensive. Computer manufacturers have resorted to other schemes to obtain better performance from the memory subsystems on high-performance computers while still using less expensive DRAM chips.

One method is to use a memory cache, a limited amount of high-speed static RAM that is used to store copies of the memory locations that are accessed most often. With a large enough memory cache and an appropriate algorithm for copying data to and from the cache, many caching systems are 90-percent effective (that is, more than 90 percent of the time, the data needed will already be in the high-speed cache). Caches are more expensive than some other methods, because they require costly, high-speed SRAM chips in addition to the RAM in the user-address space. Extra board space is also required for the memory that makes up the cache and its support circuitry.

Another method for improving memory access times uses interleaved (or bank-switched) memory. This scheme assumes that most memory accesses are sequentially ordered. Therefore, the memory is divided into two or more banks, with the sequential addresses interleaved among the banks. For example, in a 32-bit computer with two memory banks, the first 32 bits would be in bank 0, the second 32 bits in bank 1, the third 32 bits back in bank 0, and so on. This interleaving speeds sequential accesses by enabling one memory bank to be fetching a subsequent double word while the processor accesses the previous double word from the other bank. However, the benefit of overlapped accesses is not without penalty. Additional logic is required to implement the interleaved memory, and initial accesses (and consecutive accesses to the same bank) are longer than they would be if the interleaving circuitry were not present.

Interleaving improves the performance of sequential accesses, but real mode on the 80386 (which almost all current applications use) requires a segmented program structure—that is, separate (often physically separated) segments are used to store a program's code and data. As a result, memory accesses often bounce around between the code and data segments with few extended periods of sequential accesses; thus, much of the advantage of an interleaved architecture is lost.

A third alternative, and the one used in the Deskpro 386, is memory

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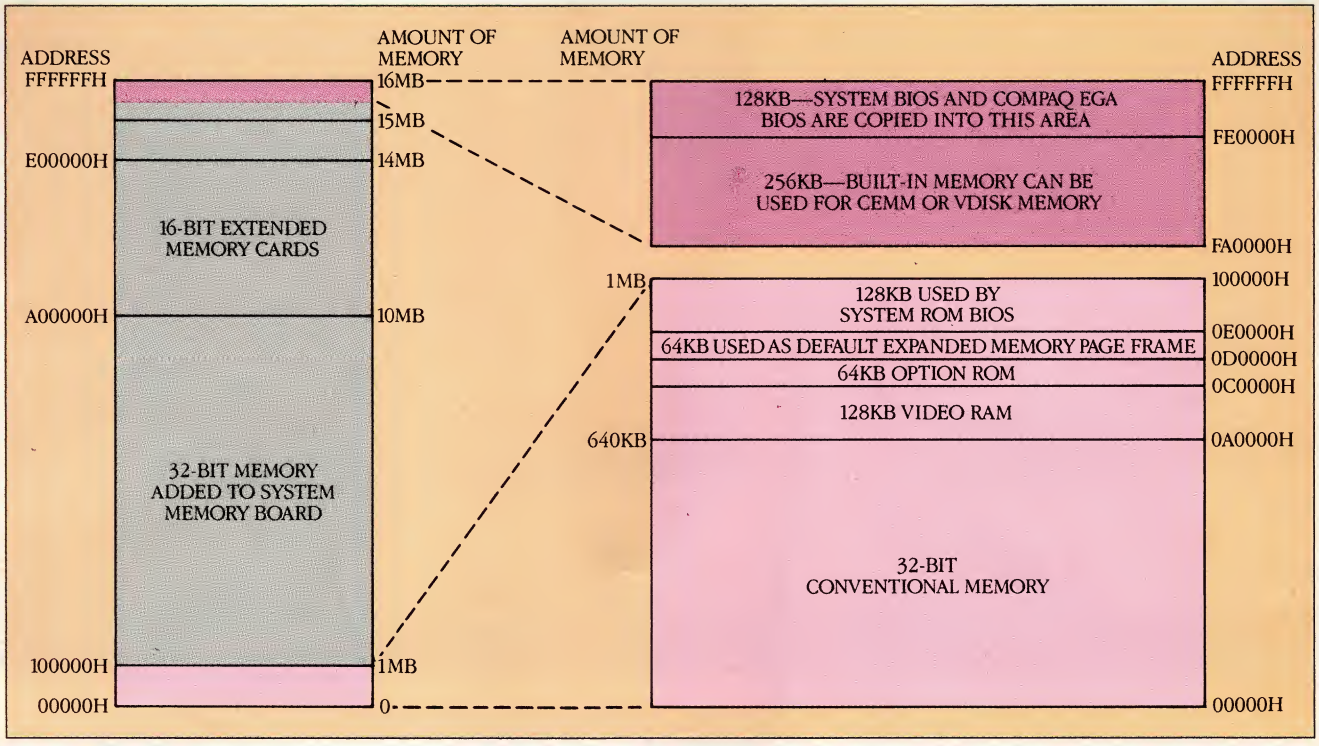
FIGURE 2: *Deskpro 386 Memory Map*



When the Deskpro 386 is set up for 640KB of conventional memory, the remaining memory in the first megabyte is located at addresses below 16MB. The BIOS is copied into the top 128KB. Other 32-bit memory is assigned addresses beginning at 1MB.

paging, in which the system RAM is divided into areas of equal size called pages. With the paging circuitry in operation, successive accesses to memory within a page are extremely fast, while successive accesses to different pages are slower. The segmented architecture of real mode negates some of the advantages of paging, just as it does with interleaving. Accessing memory outside a page boundary enacts the same type of performance penalty as consecutively accessing a single bank of an interleaved system.

The Deskpro 386 implements memory paging by using static-column RAM chips. For memory access, each 1MB bank of RAM is logically divided into rows and columns, and access to memory is obtained by presenting a row address and column address. These addresses are latched internally using the row address strobe (RAS) and column address strobe (CAS). The RAS and CAS combination identifies a specific 32-bit double word—the amount of memory that the 80386 can access in a single memory fetch. Each row and column address is a 9-bit quantity, implying 512 (or 2^9) items in each row and column. With each item being 4 bytes (32 bits) long, each page (or specific row address) of memory consists of 512 (2^9 column addresses) by 4 bytes, or 2KB of memory. With 512 of these pages, the addressing scheme is able to handle 1MB of memory. Additional 1MB banks are accessed in the same manner, with their own row and column addresses (see figure 1).

With static-column DRAM chips, memory accesses within the same page can happen with zero wait states, because the RAS is maintained from the previous memory access. When a new memory access is required, the row address is compared with the value already maintained by the memory chips. If the new row address is the same as the previous one (that is, the memory is in the same 2KB page), only a new column address needs to be presented to the DRAM. This results in a zero-wait-state access. However, if the new row address is different (that is, the memory is in a different 2KB bank), the processor must wait for the memory to recharge and present a new row address followed by column address. This process results in two wait states.

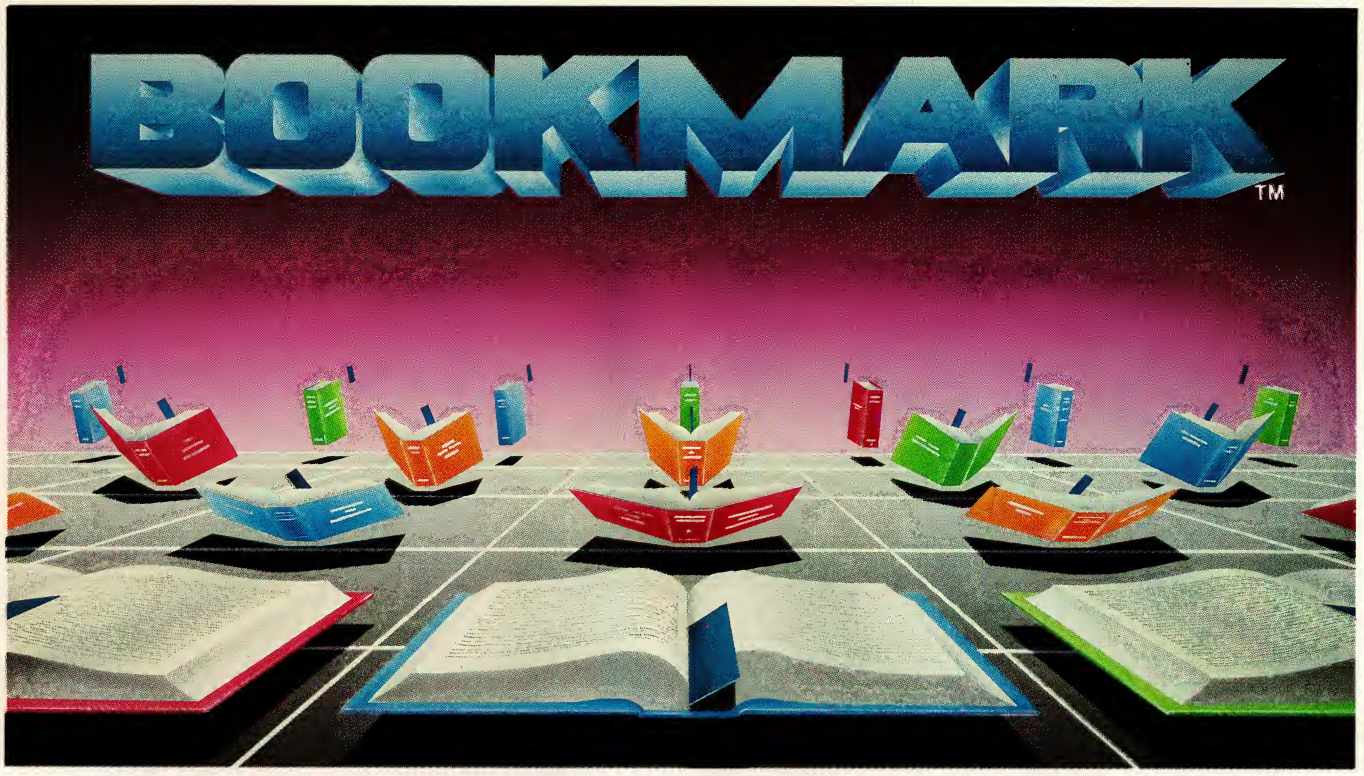
There is one situation, however, in which access to memory occurs at two wait states, even if the access is within the same page. If an idle bus cycle occurs, the memory subsystem turns off paging mode, allowing the memory subsystem to get a head start on whatever memory access it predicts will happen next. If the next access is within the same page, however, it will occur at two rather than zero wait states, because the processor will have to restart paging mode and present both a row and a column address.

Idle bus cycles are common when writing to memory because the number of processor cycles required to execute some write instructions is more than the bus cycles needed to transfer the data. Thus, idle bus cycles are inserted, which turns off the paging.

Compaq turns off paging when an idle cycle occurs because tests showed that an idle cycle typically precedes an access outside the page. Therefore, even though some accesses within a page are slowed to two wait states, overall performance is increased by 1 to 2 percent by using the idle cycle to anticipate accesses outside a page.

The paging scheme used in the Deskpro 386 complements the way that the 80386 instruction prefetch works. The sequential nature of instructions and the 80386's desire to keep the prefetch queue full enable the memory subsystem to operate within a physical page much of the time.

Compaq claims that in average circumstances, approximately 60 percent of all memory accesses occur within a page. Therefore, the memory in the



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Deskpro 386 must average 0.8 wait states per 32-bit access. For tightly coded, highly sequential applications, such as graphics drivers, it is possible to approach zero wait states.

To put these figures into perspective, consider the difference in access times between 32-bit memory on the Deskpro 386 and 8-bit memory over the PC bus. A 32-bit access within the same page on the Deskpro 386 requires 2 processor cycles (at 62.5 ns per cycle) or 125 ns. A 32-bit access outside the current page requires 4 processor cycles or 250 ns. Assuming 60 percent of the accesses occur within the current page, the average 32-bit access time is 175 ns. A similar 32-bit access from 8-bit memory requires 48 processor cycles, or approximately 3 microseconds. No wonder the Deskpro 386 seems fast.

Tests conducted for this article revealed that it was possible to achieve zero wait states when reading and writing memory. However, normal programs will not achieve this level of performance unless their memory accesses are limited to the same 2KB page. One wait state is more realistic.

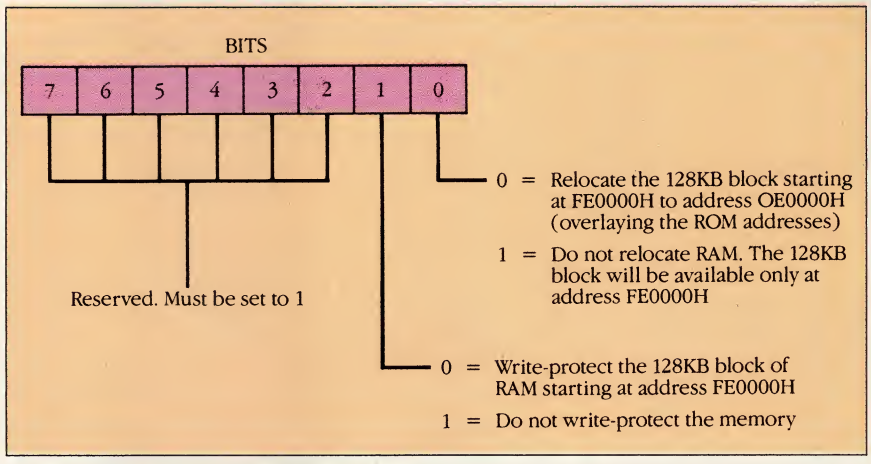
It remains to be seen whether the memory paging scheme used in the Deskpro 386 really performs better than interleaving or is more cost-effective than caching. Once the various kinds of systems become readily available, more conclusive real-world performance measurements can be taken.

NO MEMORY WASTED

In its base configuration, the Deskpro 386 contains 1MB of 32-bit RAM soldered into a system memory card that fits into the 32-bit expansion slot. With jumpers on this memory card, the user can select 256KB, 512KB, or 640KB of conventional memory. The remainder of the 1MB is automatically mapped to just beneath the 16MB address. Figure 2 shows the memory map for the most common configuration (640KB).

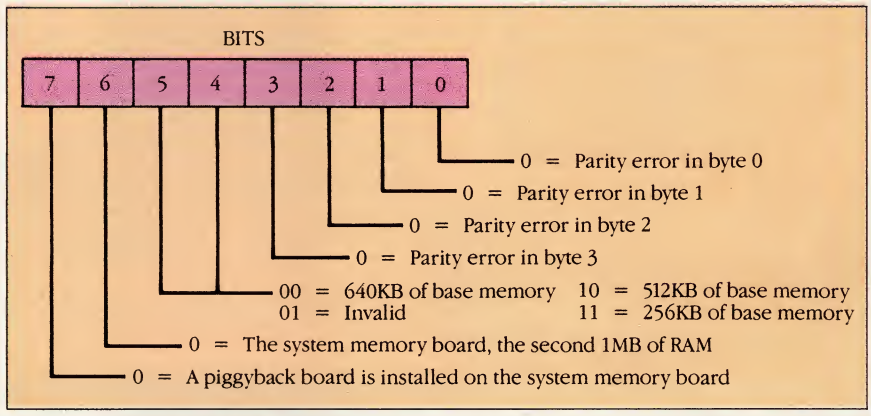
Although the extra 384KB of RAM is not available via normal DOS operations, Compaq has not let that extra memory go to waste. The uppermost 128KB segment, located at address FE0000H, is used to improve the BIOS performance. Upon start-up, the Deskpro 386 copies the system BIOS and the Compaq Enhanced Graphics Board BIOS (if available) into that memory and remaps the memory via special hardware map registers so that it replaces the 128KB area normally reserved for the system ROM (from 0E0000H to 0FFFFFH). Once this mapping takes place, applications can access

FIGURE 3: *Memory-mapped Hardware Register*



Writing to location 80C00000H sets the memory-mapped hardware register that is used to remap and write-protect the memory into which the ROM BIOS is copied.

FIGURE 4: *Memory-mapped Diagnostics Register*



Reading location 80C00000H returns the status of the memory configuration jumpers and the parity bits for each of the four bytes of a 32-bit double word.

the remapped BIOS either at address FE0000H or 0E0000H; the actual system and graphics board ROM devices are no longer accessible. Even with the remapping, this procedure relocates the graphics board BIOS, which normally starts at 0C0000H, to 0E0000H to 0F0000H. Therefore, only the BIOS from a Compaq Enhanced Graphics Board is copied because there is no assurance that another BIOS will contain position-independent code that works properly when relocated.

By remapping the BIOS into 32-bit RAM, the Deskpro 386 dramatically improves the BIOS performance. Instead of residing on 250-ns ROM chips accessed via a 16-bit bus in the case of the system BIOS or via an 8-bit bus in the case of the enhanced graphics BIOS, the remapped BIOS is accessed out of 32-bit static-column RAM. This RAM is write protected by special hardware registers so that out-of-control programs do not accidentally write to the BIOS and cause damage.

The Deskpro 386 contains a memory-mapped hardware register called the RAM relocation register that controls the mapping and write protection of this system RAM. It is a write-only register available at address 80C00000H. Bits 0 and 1 control the remapping of the ROM space and the write protection, as shown in figure 3.

Reading the same memory location (80C00000H) returns the contents of the diagnostics register. This register can pinpoint which byte within a 32-bit double word caused a parity error. It also identifies which memory is 32 bits so that diagnostics programs can use 32-bit reads and writes to speed up their RAM tests. Figure 4 shows the bit definitions of the diagnostics register.

Despite the speed improvements caused by the remapped ROM, this feature is not likely to improve overall

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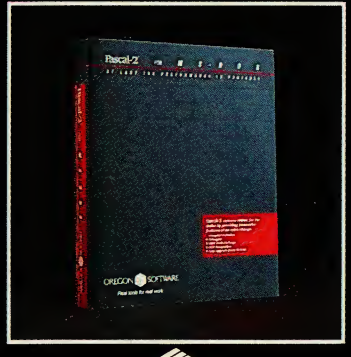

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performance appreciably. The most performance-sensitive areas of the BIOS are the screen display routines, and most applications circumvent those routines by writing directly to the display adapter RAM via the 8-bit interface. Programs that use the BIOS for screen operations, such as DIR, TYPE, and other DOS commands, are much faster. Thus, the remapped BIOS can affect users' perceptions of overall performance, simply because many people judge a computer's speed by how fast a DIR listing scrolls up the screen.

On the other hand, if the BIOS were not copied into RAM, the performance of some tight loops that use the BIOS might actually be worse than on an 80286-based computer. This degradation could occur because the 80386 is optimized for 32-bit operations, while the BIOS is contained on ROM chips accessed via the 16-bit bus.

For example, the 80386 is constantly trying to fill its prefetch queue with the instructions it expects will execute next. This prefetch queue is 32 bits wide, so each prefetch is 32 bits, whether or not the bits come in one access from 32-bit memory, two accesses from 16-bit memory, or four accesses from 8-bit memory. A prefetch of system BIOS instructions from ROM requires two separate 16-bit accesses, both of which must be completed before the processor can continue with other operations. Because of the extra time required for two separate memory accesses, a processor that was idle at the start of the prefetch might be holding up other operations by the time it finishes. This effect will be especially noticeable in programs that have small (two instruction) loops, because the jump instruction at the end of the loop flushes the prefetch queue. Users also might notice this effect if they do not use the Compaq Enhanced Graphics Board, because the Deskpro 386 will not copy non-Compaq BIOS code into RAM. In this case, four separate 8-bit accesses are required for each 32-bit fetch because the graphics board uses an 8-bit interface.

The remaining 256KB of RAM not available via normal DOS operations is referred to by Compaq as *built-in memory*. Two programs are provided to enable ordinary DOS applications to take advantage of this memory: CEMM and VDISK, a RAM-disk program. Other programs will have difficulty using this built-in memory, because it resides at high memory addresses just below the remapped BIOS. Most programs that use extended memory require that such memory begin at the 1MB address and that no gaps exist in the memory. This is not a problem, however, for the CEMM and VDISK programs. Even if other extended memory is added, CEMM and VDISK can use both the built-in memory and the other extended memory automatically.

CEMM was developed jointly with Microsoft to provide an expanded memory interface to extended memory. CEMM uses the virtual-8086 mode of the 80386 in combination with the 80386's paging capability to support the LIM expanded memory specification, without the need for special bank-switching memory boards such as Intel's Above Board. CEMM simulates the bank-switching hardware by mapping the Deskpro 386's 32-bit extended memory into the page frame specified in the LIM standard. This enables DOS applications that support the LIM specification to access additional memory up to the 8MB limit of the specification.

CEMM grants flexibility to the large amount of fast 32-bit memory that can be added to the Deskpro 386. For example, Intel's QUIKMEM2 RAM disk, which normally requires an expanded memory board, ran without difficulty from extended memory when using CEMM. The added flexibility has its cost, however. System overhead for handling interrupts increases in virtual-8086 mode because of the time required for the 80386 to switch between protected and virtual-8086 modes. Thus, programs that run in virtual-8086 mode execute approximately 5 percent slower than programs that run in real mode.

Two programs are provided to enable ordinary DOS applications to take advantage of built-in memory: CEMM and VDISK.

In addition, other programs that run in protected mode cannot be used when CEMM is active. Attempts to run such programs (RAM disks and disk caches are two examples) cause CEMM to display the following message:

Privileged Operation Error
Deactivate CEMM and Continue (C) or reBoot (B) (C/B)?

When this message occurs, the user can either deactivate the expanded memory and continue with the program or reboot the computer.

To avoid such messages when running software that uses protected mode, the user can switch expanded memory on or off from the keyboard, using the commands CEMM ON and CEMM OFF. CEMM AUTO is the default setting, making expanded memory (and its associated overhead) available when requested by an application program.

386 EXTRAS

As mentioned earlier, additional memory and piggyback cards can be added to the Deskpro 386 system memory card to supply as much as 10MB of high-speed, 32-bit RAM. Other 16-bit memory cards such as those used in the AT can be installed in addition to or in place of some of the 32-bit RAM. However, the performance difference between the 16-bit expansion bus and the 32-bit memory bus is so extreme that 16-bit memory should be added only as a last resort.

Another convenient feature of the Deskpro 386 is its processor speed control, which is designed to provide high performance while maintaining compatibility with programs that depend on program execution speed for critical timing functions. With the SPEED option of the MODE command (or BIOS interrupt 16H, AH=F0H), the processor speed can be set anywhere from slightly less than the 4.7 MHz used in the PC's 8088 to 16 MHz. Unlike the Deskpro 286, the Deskpro 386 does not support special keyboard sequences to switch in or out of any of these modes (the Deskpro 286 uses Ctrl-Alt-/ to change speeds). Only the MODE command or BIOS interrupt 16H can be used. Five options of the MODE command affect the processor speed:

MODE SPEED = COMMON
MODE SPEED = FAST
MODE SPEED = HIGH
MODE SPEED = AUTO
MODE SPEED = num

The COMMON setting causes the 80386 to simulate the speed of a 6-MHz 80286. FAST simulates an 8-MHz 80286. HIGH sets the speed to a full 16 MHz.

In AUTO mode, the default speed setting, the processor operates at full 16-MHz speed until a diskette access occurs; then it switches to 8-MHz (FAST) mode until the disk access is complete, when it switches back to 16 MHz. The BIOS recognizes when to switch speeds by keying on the diskette's motor-on switch. The AUTO mode is intended to help users install and run copy-pro-

tected programs, particularly those that require a key diskette. As Compaq realized, most copy-protection schemes are speed sensitive. With the processor slowed just during diskette accesses, the copy-protection mechanism can succeed without forcing the computer to run permanently at the slower speed. After installation (or key-diskette checking) is complete, the Deskpro 386 returns to 16-MHz operation.

The last form of the MODE SPEED command allows users to specify a numeric value from 1 to 50 for the processor speed. This form of the command corresponds to the way the speed is set using BIOS interrupt 16H and permits users to select from a large variety of speeds. Table 1 shows how these numbers correspond with the other MODE SPEED options.

The Deskpro 386 implements the speed controls by using the 80386 HOLD signal. The 80386 is in a HOLD state whenever a memory refresh occurs. Therefore, to slow down the processor, the refresh period is simply extended, reducing the amount of time that the 80386 is actually executing instructions. This method of slowing down the processor is better than adding memory wait states because it does not affect the bus bandwidth or the latency for direct memory access (or other bus master operations). However, extremely tight program loops that execute within the time of a refresh cycle and require a slowed processor might not work correctly.

The Deskpro 386 uses a signal from an 8254 interval timer to lengthen the refresh period. The 8254 timer is programmed using the values in the BIOS interrupt 16H; function request AH=F0H; the MODE SPEED=num command; or the values that correspond to the other MODE SPEED options.

Normally, the processor speed is set in its default state (AUTO). This permits 16-MHz speed during most system operations, but still allows copy-protected programs to be loaded from diskette. The other settings can be useful for running speed-sensitive programs such as games. One especially nice touch is that any selected speed survives a warm reboot of the computer. This means that even action games written especially for a 4.77-MHz 8088 can be run by first selecting a low speed, such as MODE SPEED=03 and then rebooting the computer with the game disk in drive A:.

Because the Deskpro 386 needs an 8254 signal for its speed control, it contains two 8254 timers, one more than the AT. Both timers have three separate counters. In the first timer, which provides the same functions as the 8254 on the AT, counter 0 is connected to the 8259 interrupt controller and provides the system timer interrupt for time-of-day, diskette time-out, and other system functions; counter 1 generates the refresh request signal; and counter 2 generates the tone for the speaker.

The second 8254 timer provides functions not found in the AT. Counter 1 of the second timer is unused; counter 2 extends the refresh period as just described; and counter 0 provides one of the most interesting features of the machine. It is a fail-safe timer that can generate interrupts on the nonmaskable interrupt line at regular intervals. The Compaq documentation states that operating systems can use this signal to prevent the system from locking up. It also claims that this function is intended for future operating system use. Therefore, this system "heartbeat" might be included in versions of DOS developed for the 80386 processor. A switch on the system board can turn the fail-safe timer on or off.

TABLE 1: *MODE SPEED Parameters*

SYSTEM SPEED SIMULATED	MODE COMMANDS
8088-based PC	MODE SPEED=3
6-MHz AT	MODE SPEED=COMMON or MODE SPEED=16
8-MHz AT	MODE SPEED=FAST or MODE SPEED=18
16-MHz 80386	MODE SPEED=HIGH or MODE SPEED=50

The MODE SPEED command can be used to change operating speed. This table correlates the MODE SPEED parameters with the numeric values entered.

One feature that the Deskpro 386 might be expected to contain, but does not, is a socket for an 80387 numeric coprocessor.

A Motorola MC146818 serves as the Deskpro 386's realtime clock and stores configuration information. This component, which also is used in the AT, contains 64 bytes of memory. The first 14 are used by the clock, and the last 50 are used to save the system configuration when the power is turned off. Three of the bits in configuration byte 45 (2DH) store additional information not maintained by the AT: bit 0 indicates whether Compaq's dual-mode monitor is installed; bit 1 indicates whether the audible key-click feature is enabled; and bit 3 indicates whether a Compaq or non-Compaq graphics adapter is installed.

The Deskpro 386 has other features not found in the AT, most of which are also available in the Deskpro 286. These include the Ctrl-Alt-plus and Ctrl-Alt-minus sequences to increase or reduce the loudness of the key clicks and the optional tape backup unit.

The speed and capacity of the tape backup unit has been improved over the units previously available with the Deskpro computers. Tape backup now is twice as fast as earlier models; and the new unit can back up 40MB of information instead of 10MB, because it uses the 3M DC2000 3½-inch cartridges rather than the DC1000 cartridges. For compatibility with earlier Compaq computers, the new tape unit can read the DC1000 tapes produced by other Compaq tape units, but it cannot write to them. The new tape unit can be installed in the Deskpro 286.

Unfortunately, on several occasions the tape drive in the tested unit refused to back up data successfully. It locked up during the middle of a backup operation and could not be restarted except by turning the power off and on again. The backup operation was tried at several processor speeds, but the errors still occurred frequently. These problems did not reappear when another unit was tested, but the reliability of Compaq's higher-capacity tape drives should be questioned nonetheless.

One feature that the Deskpro 386 might be expected to contain, but does not, is a socket for an 80387 numeric coprocessor. This omission probably occurred because the design of the 80387 was incomplete when the Deskpro 386 was developed. The machine does have a socket for the 80287, which has a different number of pins and a different pin layout than the 80387. A further drawback is that the Deskpro 386 supports only 4- and 8-MHz 80287s, not the 10-MHz parts that are now

widely available. A switch on the system board indicates whether a 4- or 8-MHz 80287 is installed.

LOOKING INSIDE THE 386

The box housing the system unit of the Deskpro 386 is virtually identical to that of the Deskpro 286, so the joys and sorrows of installation are also the same. On the negative side, Torx screws are used in most of the fastenings, and Torx screwdrivers are often difficult to find. Further, a metal brace is mounted on the left side of the system unit, immediately over slot one (the 32-bit slot). To take out the memory board, the brace has to be removed.

On the positive side, the cover of the system unit is held on by fewer screws on the rear panel so it is easier to remove than the cover of the Deskpro 286. Instead of selecting the correct three of eight screws, all of which look as if they need to come out, users now choose three of four screws.

Compaq has improved the installation process immensely by gluing a quick-reference card to the top of the peripheral bay enclosure. This card contains a drawing of the system board with callouts identifying all the expansion cards, the 80287 socket, the system board switches, the power supply and power connectors, and the system ROMs. In addition, it identifies the drive connectors, lists the settings for the system board switch, and lists the jumper selections for the memory board and disk controller board. With this convenient reference, the experienced user can perform almost all installation tasks without opening a manual.

The peripheral bay in the Deskpro 386 is capable of containing four half-height drives. This is a smaller area than the AT provides, but the extra space underneath the bay is filled with shock-mounting material to protect the drives from damage.

One well-designed feature is the easy-to-reach location of the 80386 and 80287 sockets on the left side of the system board. The B1 stepping of the 80386 is used in the Deskpro 386. Although this version of the 80386 has several programming anomalies, Compaq's technical reference contains 10 pages of valuable information that describes how to avoid problems with the stepping of the 80386. Most of the anomalies are of interest only to designers of protected-mode operating systems. Application programmers will rarely encounter any problems.

As shown in photo 4, the Deskpro 386 has eight expansion slots—three 8-bit slots (one of them half size), four 16-bit slots, and one 32-bit slot. The 8-bit and 16-bit slots operate at 8 MHz for compatibility with boards designed to operate in the AT. The 32-bit slot is slot 1, which is the leftmost slot in the photo. This slot consists of two connectors: an 80-pin connector positioned at the front of the system unit and a small one next to slot 2 that is actually a second set of power and ground signals for improved power distribution.

The system memory board, shown in photo 5, fits into the 32-bit slot. The board comes standard with 1MB of RAM, which is soldered in place. Sockets are available for an additional megabyte on the board, as are connectors for adding a single piggyback card. The memory board and piggyback card accept only static-column RAM chips. With the largest piggyback card installed, 10MB of RAM can be accessed from the system memory board.

The system memory board comes standard with 1MB of RAM, which is expandable to 2MB. More can be added using a piggyback card.

The system board has only one switch block. It specifies the monitor type, default speed setting, whether the numeric coprocessor is present and, if so, the speed at which it runs, and whether the fail-safe timer is enabled.

Of the remaining seven slots, two are occupied with a 40MB hard disk—one 8-bit slot by the graphics controller and one 16-bit slot by the multipurpose hard-disk controller board. The multipurpose board controls the 40MB hard disk, the diskette drives, and the tape drive. On the units with 70MB or 130MB hard disks, another 16-bit slot is occupied, because the larger capacity drives require a separate controller.

In the model 40 unit, the multipurpose hard-disk controller is connected to two diskette drives (a 1.2MB drive and a 360KB drive), a 40MB hard disk, and a 40MB tape backup unit. The two diskette drives and the tape backup unit slots are attached to a single connector on the controller in a daisy-chain fashion. The controller supports a second 40MB drive, but the power supply, the same 192-watt model used in the Deskpro 286, is not powerful enough to handle two hard disks and a tape drive. Therefore, if a second hard disk is added, the tape backup unit must not be included. To pack all of that functionality into a single controller board, Compaq uses special 40MB disks. The drives contain much of the control circuitry on the drive circuit board rather than on the controller board.

The 70MB and 130MB drives do not connect to the multipurpose controller board. Both of these drives use the ESDI interface, so they require a separate controller card that supports a single drive. Both controllers use the same I/O addresses when communicating with the hard disks, so if a 70MB or 130MB drive is included, no 40MB drives are supported.

Although only the 40MB, 70MB, and 130MB drive options are available from Compaq, the ROM BIOS supports 47 types of hard disks. Table 2 lists the drive types and characteristics. All the Deskpro 386 drive types are supported by the AT, with the same type numbers.

A serial and a parallel port are also contained on the multipurpose hard-disk controller. The serial port uses a 9-pin, male, D-shell connector. The parallel port uses a 25-pin, female, D-shell connector. These connectors are the same as those used in the AT's parallel/serial card. The serial port can be switched between COM1 and COM2. The parallel port is set to LPT1, but it can be disabled if it conflicts with the ports on other expansion cards.

STANDARD SOFTWARE

GW-BASIC version 3.0 and MS-DOS 3.10 are available at extra cost with the Deskpro 386. Included with this package is a DOS 3.2 support disk that contains a replacement set of disk utilities that works with IBM's PC-DOS 3.2 and is aware of the Deskpro 386's 40MB, 70MB, and 130MB hard disks.

Compaq's DOS 3.1 disk contains all the items that are contained in IBM's DOS 3.1, plus some extras. One of the added files is DISKINIT, a utility that simplifies setting up a hard disk. It performs the FDISK, ENHDISK, and FORMAT functions, creates CONFIG.SYS and AUTOEXEC.BAT files, and copies both DOS diskettes into a subdirectory called /DOS. These operations are similar to the ones that are performed by the SELECT command in DOS 3.2.

Other extra programs include SETCLOCK, which allows users to reset the date and time without running the set-up program; CMPQADAP, a utility for modifying the keyboard driver for

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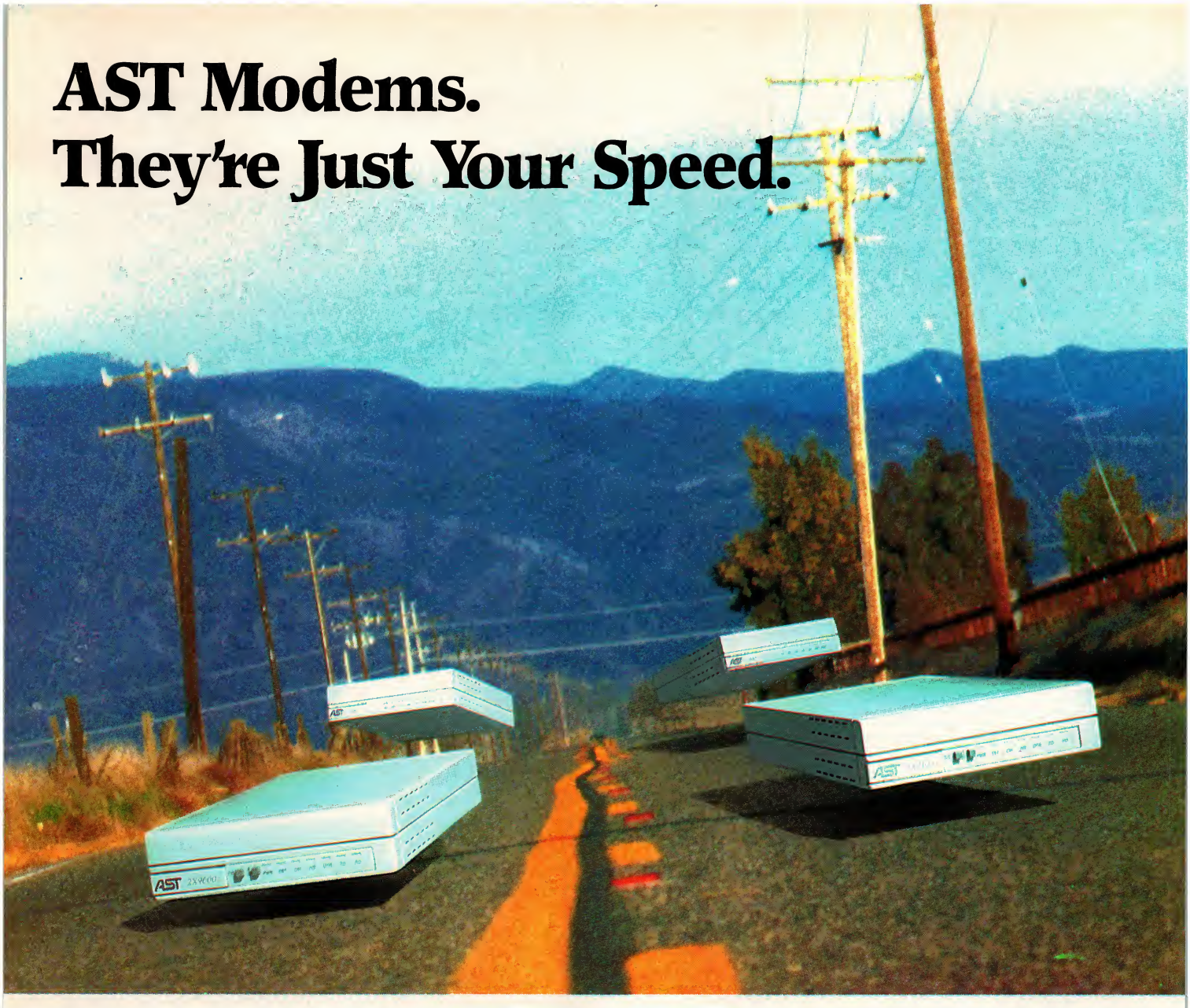

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international character sets; KEBDA, KEYBNO, KEYBSU, and KEYBSV, which are four additional keyboard drivers; GRAFTABL, which enables the color/graphics adapter when operating in graphics mode to display characters whose ASCII values are greater than 127; TAPE, a cartridge tape utility that formats a tape, backs up files to tape, restores files, lists a tape directory, and erases tapes; and SETUP, which stores configuration information in the memory of the realtime clock chip.

Software supplied with the Deskpro 386 includes ENHDISK.SYS, a driver that assigns a separate drive letter to each partition of a hard disk. This is necessary for using all the storage on the Deskpro 386's large hard disks, because DOS limits partitions to 32MB. Two CEMM programs (CEMM.EXE and CEMM.COM) are supplied, as well as INST386, which generates or modifies the CONFIG.SYS file in order to identify CEMM.EXE and VDISK.SYS as device drivers and indicate the amount of memory to be used for expanded memory and virtual disks.

Finally, Microsoft provides a diagnostic program called TEST that is the equivalent of IBM's standard diagnostics. Curiously, this program contains a test for the Microsoft InPort mouse. Compaq was rumored to be including an InPort connector on its Enhanced Graphics Board, but it is not contained on the released version. Compaq may have forgotten to remove the diagnostic test when it decided not to include the InPort connector.

Compaq continues to score high marks with its technical documentation. Included with every Deskpro 386 is a useful *Operations Guide*. Users also can purchase the excellent two-volume *Technical Reference Guide*.

The *Technical Reference Guide* is one of the finest works of its kind and an essential purchase for anyone who is curious about how the Deskpro 386 really works. It is clearly written and provides enough background material so that even novices can understand the complex topics it covers. The explanation of the 80386's B1 stepping is especially good. Unfortunately, much of the information that IBM places in its *Guide to Operations* manuals is available from Compaq only in this separately priced reference. The explanation of switch settings for the multipurpose disk controller board is one example.

Compaq produces a single set of DOS documentation for all Compaq computers, with special supplements for the Deskpro 386. While this may be

TABLE 2: *Disk Drives Supported*

DRIVE TYPE	NO. OF CYLINDERS	NO. OF HEADS	CAPACITY (MB)	LANDING ZONE CYLINDER	PRECOMPENSATION CYLINDER	SECTORS/TRACK
1	306	4	10.65	305	128	17
2	615	4	21.41	638	128	17
3	615	6	32.12	615	128	17
4	1,024	8	71.30	1,023	512	17
5	940	6	49.09	939	512	17
6	697	5	30.33	696	128	17
7	462	8	32.17	511	256	17
8	925	5	40.26	924	128	17
9	900	15	117.50	899	−1[a]	17
10	980	5	42.65	980	−1	17
11	823	10	71.63	822	−1	17
12	925	9	72.46	924	128	17
13	612	8	42.61	611	256	17
14	754	11	72.19	753	−1	17
15	0	0	0	0	0	0
16	612	4	21.31	612	0	17
17	980	5	42.65	980	128	17
18	966	6	50.45	966	128	17
19	1,023	8	71.23	1,023	−1	17
20	733	5	31.90	732	256	17
21	733	7	44.66	732	256	17
22	768	6	40.11	768	−1	17
23	771	6	20.16	771	−1	17
24	966	14	117.71	966	−1	17
25	966	16	134.53	966	−1	17
26	1,023	14	124.66	1,023	−1	17
27	966	10	84.08	966	−1	17
28	771	3	20.11	771	−1	17
29	578	4	20.09	578	−1	17
30	615	4	31.49	615	128	25
31	615	8	62.98	615	128	25
32	966	3	50.45	966	−1	34
33	966	5	84.08	966	−1	34
34	966	7	117.71	966	−1	34
35	966	8	134.53	966	−1	34
36	966	9	151.35	966	−1	34
37	966	5	84.08	966	−1	34
38	1,023	9	155.56	1,023	−1	33
39	1,023	11	190.13	1,023	−1	33
40	1,023	13	224.70	1,023	−1	33
41	1,023	15	259.27	1,023	−1	33
42	1,023	16	284.93	1,023	−1	34
43	756	4	40.26	756	−1	26
44	756	2	20.13	756	−1	26
45	756	4	40.89	768	−1	26
46	768	2	20.45	768	−1	26
47	966	5	61.82	966	128	25

[a]*The −1 values mean that no write precompensation is used for the drive.*

The Deskpro 386 BIOS supports 47 drive types. These include all the drive types (with the same type numbers) supported by the IBM AT, plus many more. This allows a high degree of flexibility in the selection of disk drives.

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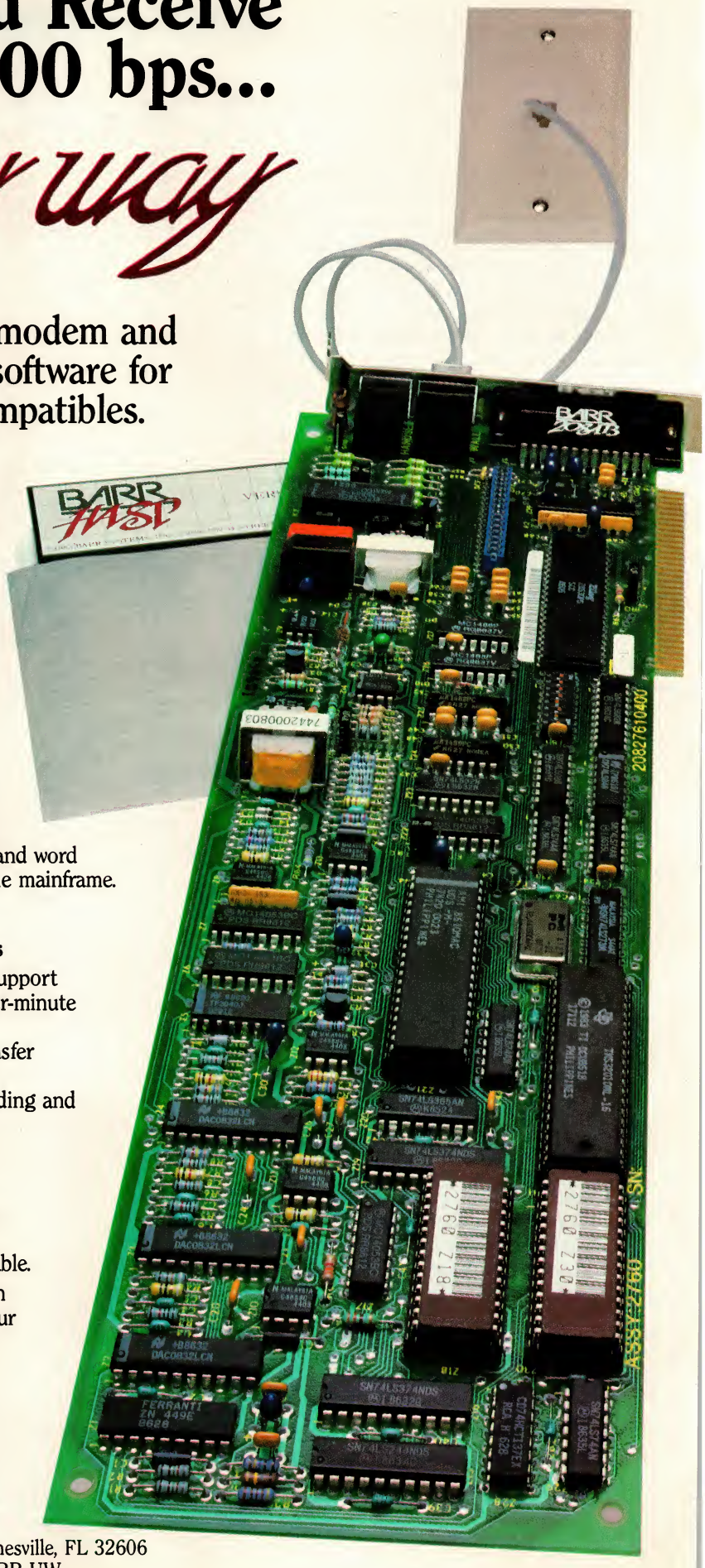

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convenient for Compaq, it creates a great deal of confusion for the user. The DOS 3.1 documentation and diskettes form a generic package that is available with all Compaq computers. Two other diskettes, the User Prog and Supplemental User Prog diskettes, contain additional utilities as well as updated versions of certain programs and versions designed especially for the Deskpro 386. For example, the User Prog diskette contains a new version of the TAPE program that must be used instead of the version on the DOS diskettes. The Supplemental User Prog diskette contains versions of VDISK and the MODE command designed for the 80386 processor. Nowhere does the DOS manual mention the existence of these updated programs. Nor does the DOS manual describe the CEMM program. The Deskpro 386 *Operations Guide* mentions the new VDISK, CEMM, and MODE versions, but not the new TAPE command. With multiple copies of programs and utilities, the user can easily install the wrong versions. The manuals do nothing to explain the situation or ease the problem.

Instead of the usual 90-day warranty, Compaq provides a one-year warranty for the Deskpro 386, including the Enhanced Graphics Board and Compaq Color Monitor. If users experience problems during that time, they can return the machine to their dealer for repairs or replacement.

TEST RUN

The Deskpro 386 was subjected to the same tests used throughout this series on AT compatibles, although they were modified to run on 80386-based computers. First, commonly used software and hardware products were installed to check for compatibility. Then the *PC Tech Journal* AT Evaluation Suite of compatibility and performance tests was run and the results were compared with those of the 8-MHz IBM AT. (For details on how these tests were modified, see "Updating the Evaluation Suite," Ted Forgeron, Paul Pierce, and Steven Armbrust, this issue, p. 70).

All of the hardware products tested with the Deskpro 386 worked without problem, including an 80287 numeric coprocessor, an Intel Above Board with 4MB of memory, Microsoft serial and bus mice, a Hayes Smartmodem 1200, and the Compaq Enhanced Graphics Board. One item worth special mention is that expanded memory on the Above Board (or on any expanded memory board) cannot be used when Compaq's CEMM driver is installed. The reason for this is simply because only one expanded memory driver can be active at any one time in one computer.

Software installed in the Deskpro 386 included Microsoft Windows 1.01 and Microsoft Word 3.1 to test graphics capabilities and the mouse; Borland's SuperKey 1.11A, SideKick 1.56A, and Turbo Lightning 1.101A to test memory-resident programs; Living Videotext's Ready! 1.00C and Intel's QUIKMEM2 RAM disk to test expanded memory; both the IBM and Compaq versions of VDISK to check the computer's ability to switch in and out of protected mode; Fastback from Fifth Generation Systems to test direct memory access; and the IBM Advanced Diagnostics programs to perform a general check-up.

The Technical Reference Guide is an essential purchase for anyone who is curious about how the Deskpro 386 really works.

Almost all the programs worked without error. Only SuperKey failed completely by locking the enhanced keyboard, but a new version (1.15) released specifically to solve this problem worked as advertised on the Deskpro 386. Fastback performed without errors, but the restore program required the processor speed to be set to 8 MHz. The only other program that showed a discrepancy was the IBM Advanced Diagnostics program, which recognized only 640KB of the Deskpro 386's first 1MB of RAM. The remaining 360KB is mapped to addresses that are just below 16MB, where the Diagnostics program could not find it.

The expanded memory programs (Ready! and QUIKMEM2) were tested by running them out of CEMM memory; both ran without problems.

The IBM VDISK program also worked as intended. This is significant because it implies that even though the 80386 can easily switch between protected and real modes, the Deskpro 386 also supports the more complicated method required for the 80286 (which involves resetting the processor). The Deskpro 386's VDISK program is written especially for the 80386 processor and does not need to reset the processor to go back to real mode.

One other program tested on the Deskpro 386 did not run correctly. Gold Hill Computers' Golden Common LISP (GCLISP) large memory version 2.0, a program that switches in and out of protected mode to execute code out of extended memory, caused the computer to perform a warm reboot. Gold Hill attributes the problem to the aggressive, nonstandard way that GCLISP uses 80286 protected mode. Gold Hill plans to market a Deskpro 386-compatible version of GCLISP in 1987.

The *PC Tech Journal* compatibility and performance tests consist of five programs: ATBIOS checks the BIOS and BIOS data areas; ATKEY checks for keyboard compatibility; ATFLOAT measures floating-point operations with the numeric coprocessor installed; ATDISK measures hard-disk performance; ATPERF measures processor and numeric coprocessor clock rates, as well as memory access times. Table 3 lists the results of these tests, and figure 5 presents bar-graph comparisons between the 8-MHz AT and Deskpro 386 for RAM instruction fetch, RAM read and write times, ROM read times, and EMM read and write times.

ATBIOS showed that the Deskpro 386 uses the BIOS data area in the same way as the AT. It listed a Compaq copyright and a date of 8/19/86.

ATKEY verified the keyboard compatibility. The original AT keyboard also worked with the Deskpro 386.

ATFLOAT showed that the Deskpro 386 can process floating-point operations 1.7 times as fast as an 8-MHz AT. Given that the processor runs at 16 MHz and the numeric coprocessor at 8 MHz (compared to 8 and 5.33 on the AT), this value seems appropriate.

ATDISK proved that the 40MB drive in the Deskpro 386 is a high-performance model consistent with the requirements of an 80386-based computer. It showed considerably better access times than the IBM drive, and it is formatted and works effectively with an interleave of 2, causing a higher effective transfer rate than the IBM drive (which uses an interleave of 3).

The most interesting results were obtained from ATPERF, which demonstrated that the Deskpro 386 is an extremely fast computer, with instruction fetches, as well as memory reads and writes, almost three times as fast as an 8-MHz AT. (Because the system normally runs at 8 MHz when the diskette drive is accessed, ATPERF must be run from the hard disk or SPEED must be set to HIGH using the MODE command to achieve these results.)

The RAM read and write times and the corresponding wait states show the values expected from a high-performance, 32-bit processor. ATPERF shows that reading from and writing to RAM within a 2KB page indeed occurs at zero wait states.

The modified version of ATPERF uses PUSHA instructions to measure RAM writes. These are fast instructions that do not result in idle bus cycles. Each PUSHA instruction involves eight PUSH instructions (pushing all of the registers), and therefore it writes to eight consecutive memory locations that are almost always within the same 2KB page. Memory is accessed outside the page when the processor fetches a new instruction. However, each PUSHA is a byte instruction, so each instruction fetch during this test fetches four separate PUSHA instructions (the 80386 accesses four bytes at a time). As a result, each instruction fetch results in 32 memory accesses (eight pushes from each of four PUSHA instructions). With this mechanism, the effect of accessing memory outside of a page during instruction fetch is barely noticeable and is not enough to affect the number of wait states measured.

The ROM read times are also worth discussing. ATPERF checks the ROM read time by using MOVS instructions to copy the system BIOS to RAM. However, in the Deskpro 386 the system BIOS reads are actually performed from RAM instead of ROM. Therefore, the ROM read times are, in fact, equal to the RAM read times as indicated in table 3, with the actual performance dependent upon the extent to which successive memory accesses occur within the same 2KB page.

The ROM read test is a general-purpose test that is not customized for the Deskpro 386. It subtracts the average RAM write time that was discussed previously from the average time required to copy ROM to RAM in order to determine the average ROM read time. In the case of the Deskpro 386, the average RAM write time is measured at zero wait states, whereas the RAM writes in the ROM copy operation occur at two wait states (because the MOVS source and destination addresses are not in the same 2KB page.) Therefore, subtracting the zero-wait-state average write time yields an inaccurate value for average ROM read time.

The value that is displayed (0.39 microseconds) is quite useful, however, for determining the average time needed for RAM read/write accesses that are not contained within the same 2KB

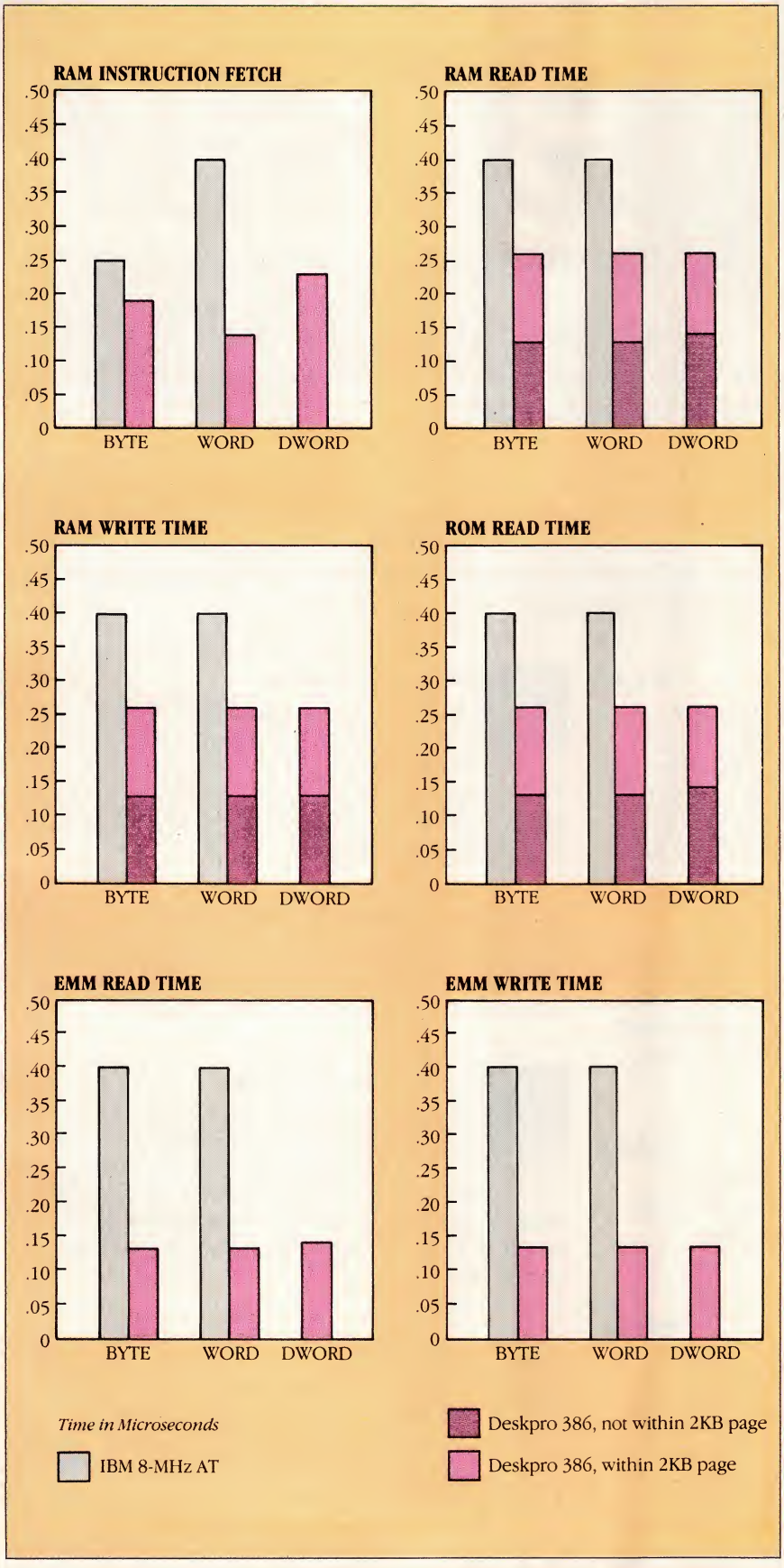
TABLE 3: *Compatibility and Performance Tests*

	8-MHz AT, 30MB DISK[a]	DESKPRO 386, 40MB DISK
ATBIOS		
ROM BIOS date	11/15/85	08/19/86
ATPERF		
Average RAM instruction fetch (μs)		
BYTE	.250	.19 (130)[b]
WORD	.403	.14 (280)
DWORD	N/A	.23
Average RAM read time (μs)[c]		
BYTE	.401	.13/.26 (298/154)
WORD	.401	.13/.26 (298/154)
DWORD	N/A	.14/.26
Average RAM write time (μs)[c]		
BYTE	.401	.13/.26 (307/154)
WORD	.401	.13/.26 (307/154)
DWORD	N/A	.13/.26
Average ROM read time (μs)		
BYTE	.401	Same as RAM read
WORD	.401	Same as RAM read
DWORD	N/A	Same as RAM read
Average CGA video write time (μs)		
BYTE	1.208	1.21 (100)
WORD	2.415	2.42 (100)
DWORD	N/A	4.83
Average EMM read time (μs)		
BYTE	.402	.13 (301)[d]
WORD	.402	.13 (301)[d]
DWORD	N/A	.14
Average EMM write time (μs)		
BYTE	.402	.13 (306)
WORD	.402	.13 (306)
DWORD	N/A	.13
CPU clock rate (MHz)	8.0	16.0 (200)
Numeric coprocessor clock rate (MHz)	5.3	8.0 (150)
Refresh overhead (%)	7.1	15
RAM read/write wait states	1/1	0/0
ROM read wait states	1	2
Video write wait states (CGA)	8	17
EMM read/write wait states	1/1	0/1[d]
ATFLOAT		
Performance as percentage relative to AT	100	107
ATDISK		
Sectors/track	17	17
Heads	5	5
Cylinders	731	978
Total space (million bytes)	31.81	42.56
Track-track seek time (ms)	6.0	4.1
Average seek time (ms)	37.1	27.6
Effective transfer rate (KB/sec)	170.1	254.5
DOS file I/O (sec)	7.3	7.4
Interleave	3	2

[a]The figures for the IBM AT are the average results from several machines, whereas the results from the Compaq Deskpro 386 are taken only from the review sample model.
[b]Figures shown in parentheses represent the relative performance expressed as a percentage compared to PC Tech Journal*'s baseline machine, the 8-MHz, 30MB AT.*
[c]For the Deskpro 386, first number is for memory access within the same 2KB page; the second is not within the same 2KB page.
[d]EMM measurements were taken using the Deskpro 386's CEMM driver and built-in memory.

RAM read/write times are from 1.5 to 3 times faster that for the AT, depending on whether or not successive accesses are written to the same 2KB page.

FIGURE 5: *Performance Comparison*



The Deskpro 386 can access a 32-bit double word faster than the AT can perform even one of the two 16-bit word accesses that it uses to perform the same task.

page. This value is determined by adding the previously subtracted average RAM write time to the average ROM read time displayed by ATPERF and then dividing that total by two (because the RAM reads and writes take the same amount of time). The resultant 0.26 microseconds per double word is the expected average time for a two-wait-state RAM read/write.

FASTEST ON MARKET

For anyone who demands high performance and AT compatibility, the Compaq Deskpro 386 is definitely the computer of choice. At the time this review was written, it was easily the fastest AT compatible on the market, as well as one of the most compatible. The addition of Compaq's special touches, such as processor speed control, CEMM, and excellent documentation, make this computer even more desirable. Perhaps its best and brightest feature is its 80386, which offers a bridge between today's real-mode applications and tomorrow's more powerful multitasking and protected mode programs.

Only a few areas need improvement in the Deskpro 386. The absence of a socket for the 80387 numeric coprocessor will keep this machine's floating-point performance less than that provided by other new 80386-based machines that do support the 80387. Even other computers that contain 10-MHz 80287s will be able to edge the Deskpro 386's 4- and 8-MHz 80287 in floating-point performance. Other areas of concern are the tape backup drive, because one of the units examined did not work properly, and the Compaq Color Monitor, because it does not match the quality of some of the other enhanced color monitors that are currently on the market.

These are problems, however, that can be remedied, and they are far outweighed by the outstanding performance and quality of the Deskpro 386. Even IBM will have a hard time topping this machine.

Compaq Computer Corp.
2033 FM 149
Houston, TX 77070
713/370-0670
Deskpro 386
CIRCLE 342 ON READER SERVICE CARD

Steven Armbrust is a freelance technical writer, and Ted Forgeron is software project manager for Intel Scientific Computers. Together, they are the authors of the Programmer's Reference Manual for IBM Personal Computers *(Dow-Jones Irwin, 1986).*

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CIRCLE NO. 195 ON READER SERVICE CARD

DATA TYPES:

Numeric Data:
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REAL, range: Single Precision 8.43×10^{-37} to 3.37×10^{38}
Double precision 4.19×10^{-307} to 1.67×10^{308}
Binary Math, Single/Double/Mixed Precision
Mixed mode numeric expressions will always be REAL.

String data:
Variable from 0 to 32767 characters in size.

Record Variables:
Allows grouping of dissimilar data types into a single logical variable. Elements of a RECORD are addressed as FIELDS and can be of any type, including ARRAY, RECORD and POINTER.

Array Variables:
N-dimensional arrays of any type, including ARRAY, RECORD and POINTER. Dynamic arrays like PC-BASICA

Pointer Variables:
Allows indirect reference to any data type. Can be used with RECORD variable to create linked lists, or to create relational data structures.

In addition supports PC-BASICA record types.

BetterBASIC BENCHMARK COMPARISON

in milliseconds

	Better BASIC			IBM INTERPRETIVE		IBM COMPILED	
	SP*	DP*	8087 DP	SP	DP	SP	DP
REAL FOR/NEXT	1.3	1.4	0.55	0.93	0.93	0.7	0.7
ASSIGNMENT	1.0	1.0	0.93	1.5	1.5	0.1	0.1
ADD	0.77	1.1	0.44	1.6	2.3	0.4	0.4
MULTIPLY	0.88	1.8	0.49	1.9	3.0	0.5	0.8
DIVISION	1.0	3.0	0.49	2.8	19.7	0.6	1.1
LOGARITHM	5.7	15.6	0.55	7.5	64.0	4.0	11.9
EXPONENTIAL	7.4	27.0	0.66	6.5	43.0	3.6	10.8
SINE	4.7	17.0	0.82	17.6	35.0	3.2	12.4
COSINE	4.5	17.0	0.77	25.0	41.0	3.5	12.7
TANGENT	7.2	18.0	0.66	44.0	94.0	6.9	26.0
X^Y	13.8	44.5	1.1	15.2	115.0	7.7	24.0
SQR (SQUARE ROOT)	1.4	6.5	0.33	7.2	95.0	1.1	3.5

*SP = Single Precision
DP = Double Precision

BYTE ARRAY PTR	INTEGER	PUBLIC	STRING
BYTE ARRAY STRUC	INTEGER ARG	READ RECORD	STRING ARG
BYTE PTR	INTEGER ARRAY	READCHR	STRING ARRAY
CHANGE	INTEGER ARRAY ARG	READCHR FROM	STRING ARRAY ARG
CHAR$	INTEGER ARRAY PTR	READLINE	STRING ARRAY PTR
CHECK	INTEGER ARRAY STRUC	READLINE FROM	STRING ARRAY STRUC
CLD	INTEGER FUNCTION	READ RECORD	STRING FUNCTION
CLW	INTEGER PTR	REAL	STRING PTR
CODE	INTERRUPT	REAL ARG	STRUCTURE
COLOR BORDER	INTERRUPT CLEAR	REAL ARRAY	SYSCALL
COMMAND$	INTERRUPT ON/OFF	REAL ARRAY ARG	SYSCODE
COMPRESS	INTERRUPT PROC	REAL ARRAY STRUC	SYSFLAGS
CONSTANT	INTERRUPT RESTORE	REAL FUNCTION	TYPE
DEFINE WINDOW	INTERRUPT SAVE	REAL PTR	UPPER$
DEL$	INTR	RENAME	WHILE . . . DO
DIR$	KEY=	REPEAT	WINDOW
DISABLE	KEYWORD ARG	RESTART	WOR
DO	KEYWORD SET	RESTORE PAR	WRITE RECORD
DO IF	LIST ALL	RESTORE SCREEN	WRITE TO
DO UNTIL	MAIN	RESULT=	XMEM
DO X TIMES	MAKE MODULE	RETRY	XMEM=
DRIVE$		ROT	XREF
DYNAMIC		SAVE MODULE	
END DO			
END FUNCTION			

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MERGE	ON PEN	STICK	USR
	ON STRIG		

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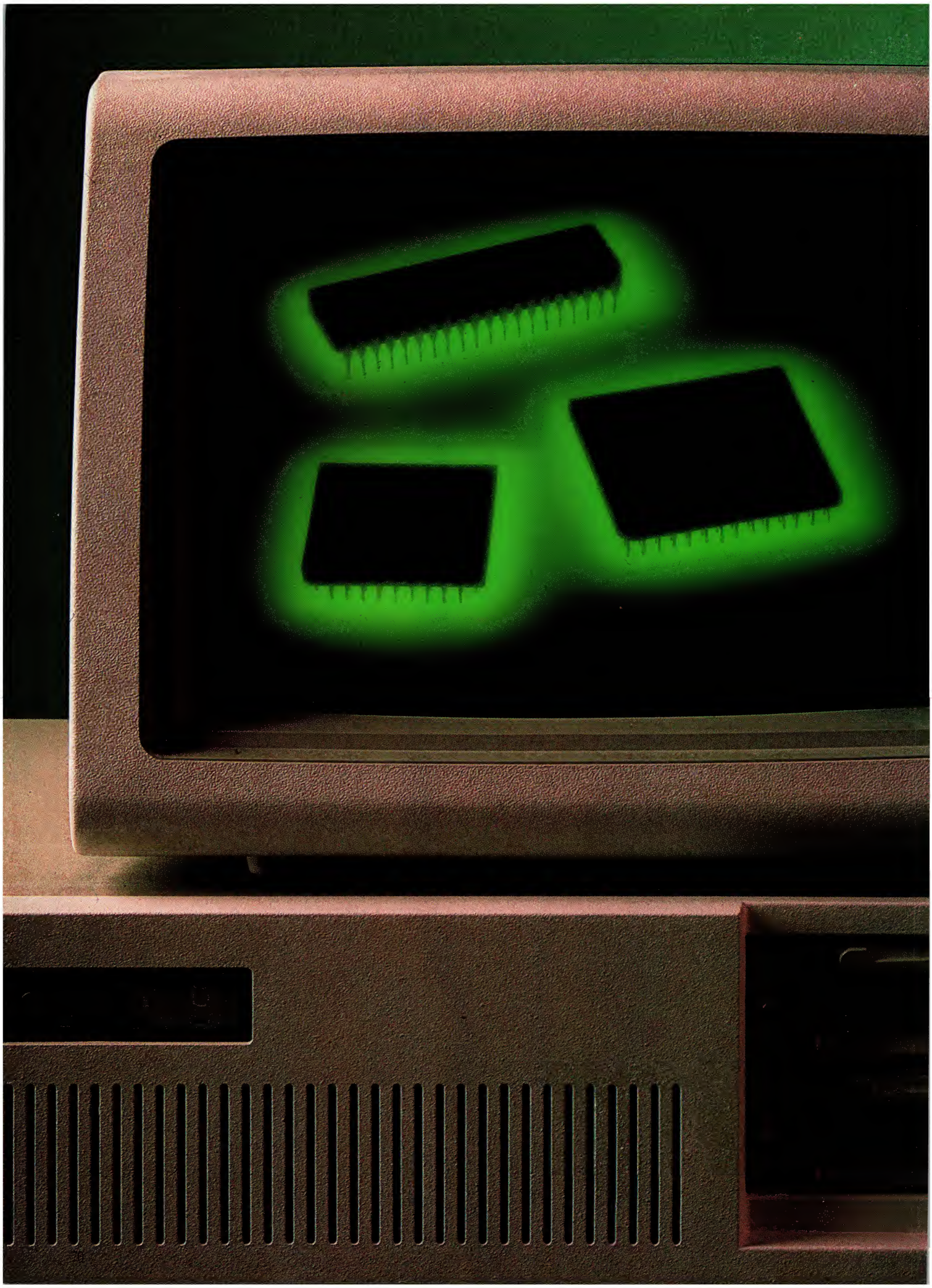

Updating the Evaluation Suite

As the state of the art progresses, so must our testing procedures. PC Tech Journal's compatibility and performance metrics have been expanded to include other processors.

TED FORGERON, PAUL PIERCE, and STEVEN ARMBRUST

For several months, *PC Tech Journal* has been reviewing 80286-based computers, examining whether or not they are compatible with the IBM PC/AT and how they perform compared to the 8-MHz AT, as well as the characteristics that make these computers unique. An integral part of these reviews has been a group of programs referred to as the AT Evaluation Suite. These programs were introduced in the article "Out from the Shadow of IBM . . .," (Steven Armbrust, Ted Forgeron, and Paul Pierce, August 1986, p. 52), which described the tests and listed their source code.

Now that Compaq has introduced an AT compatible based on Intel's new high-performance 80386, the tests had to be revised in order to measure the performance of 386-based machines.

REVISED TESTS

The compatibility tests consist of five separate programs. ATBIOS examines the computer's BIOS. ATKEY tests keyboard compatibility and programmability. ATPERF measures processor and memory performance. ATFLOAT measures the performance of floating-point operations. ATDISK measures hard-disk performance.

Because these programs were originally designed to test AT-compatible computers, they assumed that each computer contained an 80286 micro-

PHOTOGRAPH • MARC DAVID COHEN

processor. In particular, ATPERF calculated many of its results by assuming the number of clock cycles required for particular instructions. Because this number can vary from processor to processor, ATPERF gave valid results only when the computer on which it ran contained an 80286. Revised listings for ATPERF are included in this article. Small changes also have been made to the other programs to correct minor problems, but only the affected sections of code are given here. Complete listings for all the programs are available on PCTECHline.

ATBIOS. ATBIOS has been updated to version 1.01 by correcting the problems that were previously reported in the Letters column ("The Shadow of a Doubt," December 1986, p. 16). Three changes have been made.

First, when control characters appeared in the range of memory that ATBIOS checked for copyright messages, the program sometimes printed random characters to the screen instead of the copyright statement. Version 1.01 filters out control characters by displaying them as periods, much as DEBUG handles nonprinting characters. The fix involves removing the following lines:

```
write ('Copyright Statement is ');
window (40,6,80,7);
gotoxy (1,1);
write (copyright);
window (1,1,80,25);
gotoxy (1,8);
```

and replacing them with these lines:

```
write ('Copyright Statement is ');
write ('                              ');
FOR i := 1 TO 80 DO
  BEGIN
    IF (copyright [i2H < ' ')
    OR (copyright2Gi2H > '~') THEN
      write ('.')
    ELSE
      write (copyright[i]);
    IF i = 40 THEN
      BEGIN
        writeln;
        write ('                              ');
        write ('                               ');
      END;
    END;
  writeln;
```

The second problem involved ATBIOS's inability to recognize the IBM game adapter, which the AT does not support. Because the AT never sets the game adapter bit in the equipment flag, ATBIOS was fooled into thinking the game adapter was not present, even when it was installed. The new version now checks that bit only for non-AT machines. The change involves removing the following lines:

```
write ('Game Adapter Present');
write ('                    ');
if (equip_flag and game_mask) <> 0
then writeln ('YES')
else writeln ('NO');
```

and replacing them with these:

```
IF machine_id <> at_id THEN
  BEGIN
    write ('Game Adapter Present') ;
    write ('                    ');
    IF (equip_flag AND game_mask)
      < > 0 THEN writeln ('YES')
    ELSE
      writeln ('NO');
  END;
```

Finally, ATBIOS was changed to support I/O redirection so that a user can redirect the output to a file or printer. This change involves adding the following line:

```
{$P512}
```

anywhere before the first line of source code in ATBIOS.PAS.

ATKEY. ATKEY has not changed since it was introduced. This test works only with AT-compatible keyboards, not PC or XT keyboards. This is now the only one of the compatibility and performance tests that is specific to the AT.

ATPERF. Instead of a separate program that works only on 80386 machines, the new version of ATPERF is designed to run on a number of Intel processors. In fact, it can run on the 8088, 8086, 80286, and 80386, and it displays the type of processor contained in the computer. Changes also have been made to support zero-wait-state memory, such as that contained in IBM's XT-286. Like the original program, the new version is written in Microsoft C (ATPERF.C) with a MASM assembly language subroutine (TIME.ASM). Listings 1 and 2 contain the new source code for these routines.

In order to support several processors, ATPERF had to be modified so that it could detect the specific type of processor that is contained in the computer. The procedure called _CPU_TYPE that is in the TIME.ASM program performs part of this operation. The technique that is used in _CPU_TYPE is an Intel-approved method that is listed in the *Technical Reference Guide for Compaq's Deskpro 386*.

Compaq's procedure tests for the 8086/88, 80286, and 80386. It relies on the behavior of the FLAGS register in real mode, which differs among the processor types. The most significant bit of the FLAGS register (bit 15) distinguishes the 8086/88 from the other two types. In the 8086/88, bit 15 is always set to 1, whereas in the 80286 and 80386, its value is 0. Bits 12 through 14 are used to distinguish the 80286 from the 80386. In the 80286, these bits are always 0; however, the 80386 allows these bits to be set.

Armed with information about the Intel processor family, ATPERF invokes a procedure that is geared specifically toward that particular processor. Each of these procedures uses information about that processor (such as the number of processor cycles required to execute a particular instruction) when calculating the results of its tests. The procedure **measure88** tests the performance of computers that contain either the 8086 or 8088. The procedures **measure286** and **measure386** are called when the computer contains the 80286 or 80386, respectively.

When **measure88** runs, the results are used to distinguish between the 8- and 16-bit members of the family (between the 8088 and 8086). It does this by comparing the speed of two instructions: clear carry flag (CLC) and decimal adjust register AL after addition (DAA). CLC is a very fast, single-byte instruction, the speed of which is limited by the instruction fetch time. On an 8-bit computer, the execution speed of CLC is equal to the instruction fetch time. However, on 16-bit computers, CLC executes faster because instructions are fetched two at a time. DAA is a single-byte instruction that takes four CPU clock cycles to execute, about the same as an instruction fetch. Therefore, even though 16-bit computers can fetch two instructions at once, only one can be executed in that time. If the measurements for CLC and DAA are approximately equal, then the computer is of the 8-bit variety. If the CLC instruction takes less time, then the test is running on a 16-bit computer.

The **measure88** procedure performs a subset of the measurements performed by the 80286 and 80386 versions. It measures only the processor and numeric coprocessor speeds and the time for an instruction fetch (both byte and word). It performs these tests in the same way that the original version did. Processor speed is measured by executing a series of MUL instructions, each of which takes much longer than the number of cycles needed to fill the prefetch queue. Byte and word instruction fetches are measured by executing a series of CLC (byte) and MOV (word) instructions. These instructions take less time to execute than to fetch,

so this part of the test measures just the instruction fetching.

Measurements for memory read and write operations are not included in the **measure88** procedure. These operations cannot be measured accurately in the 8086 and 8088 processors because none of the memory reference instructions executes in less time than an instruction fetch.

The **measure286** and **measure386** procedures perform almost identical operations. The measurements they take are the same ones taken by the original ATPERF, with the addition of byte instruction fetches in both procedures and the 32-bit memory accesses that are included in **measure386**. The two procedures differ only in the assumptions each makes about the number of clock cycles that are required to execute certain instructions.

The mechanism that **measure286** and **measure386** use for measuring read and write times is slightly different than the method used in the earlier version of ATPERF. Previously, STO instructions were used to measure memory writes, and that value was then subtracted from a MOVS measurement (which includes both reading and writing) to obtain the value for memory read. The new version measures memory write with PUSHA instructions, which are much faster and can be used to test zero-wait-state memory. This change was made to handle the faster memory used in many of the new computers. STO instructions were limited to measuring one-wait-state memory or slower. With zero-wait-state memory, the STO instructions actually execute more slowly than their corresponding memory access, thereby invalidating the measurement that is obtained.

The Microsoft C compiler and Macro Assembler are used to produce the object code of the ATPERF program. Given that ATPERF.C contains the C source code and TIME.ASM contains the assembly language source code, the following commands are used to compile and link the program:

```
msc atperf.c;;
masm time.asm/r;;;
link atperf+time/map/stack:4000;;;
```

The **/r** option on the **masm** command directs the assembler to generate floating-point instructions that can be executed on the numeric coprocessor. The **/stack:4000** option of the **link** command directs the linker to assign a stack of 4,000 bytes to the program. This option, along with the large stack it generates, is essential for running the new version of ATPERF. Because a series of PUSHA instructions is used to measure memory write operations, a large stack is necessary to contain the pushed values. The other option on the **link** command, **/map**, is not necessary for proper program execution; however, it does provide a link map that is quite helpful for debugging.

ATFLOAT. The ATFLOAT test has been updated to version 1.02 by correcting two lines of the program, both of which deal with displaying random characters to the screen. In the previous version of ATFLOAT, the time function, which always requires a pointer to a return value, used an uninitialized value for its return pointer. This sometimes caused random characters to appear. Version 1.02 replaces the line:

```
start = time();
```

with the line:

```
start = time(NULL);
```

and also replaces the line:

```
total = time() - start;
```

with:

```
total = time(NULL) - start;
```

ATDISK. ATDISK seemed to work fine when it was compiled under Microsoft C version 3.0. However, version 4.0 of the C compiler reported compile errors, because the program used structures when it should have used unions. The latest version of ATDISK (1.01) corrects the problem by replacing six instances of the line:

```
struct REGS regs;
```

with the line:

```
union REGS regs;
```

The updated compatibility and performance tests have performed their first job on the Compaq Deskpro 386, reviewed in this issue on p. 48. Because of the changes made to ATPERF, the program was able to identify the processor in the Deskpro and perform tests suitable for the 386.

Ted Forgeron, software project manager for Intel Scientific Computers, and Steven Armbrust, a technical writer, have reviewed several AT compatibles for PC Tech Journal. *With Paul Pierce, a software consultant, they devised the original AT Evaluation Suite.*

LISTING 1: ATPERF.C

```
/* ATPERF -- PC Tech Journal AT Hardware Performance Test
 * Version 2.00 Originally written 05/17/86
 * Last modified 12/18/86
 * Changes: 1. First release (1.00).
 *      2. Correct to work with zero-wait state memory (1.01).
 *      3. Detects an unsupported processor (1.01).
 *      4. Change to support 8088, 8086, 80188, 80186 and 80386 (2.00).
 * Copyright (c) 1986, 1987, Ziff Communications Company
 * Program by: Ted Forgeron, Paul Pierce
 * Measures clock rates and memory speeds
 * of PC and AT compatible computers. */

#define IRB     0       /* Instruction fetch, byte      */
#define IRW     1       /* Instruction fetch, word      */
#define IRX     2       /* Instruction fetch, slow byte */
#define MRB     3       /* RAM read byte                */
#define MWB     4       /* RAM write byte               */
#define RRB     5       /* ROM read byte                */
#define ERB     6       /* EMM read byte                */
#define EWB     7       /* EMM write byte               */
#define VWB     8       /* Video write byte             */
#define MRW     9       /* RAM read word                */
#define MWW    10       /* RAM write word               */
#define RRW    11       /* ROM read word                */
#define ERW    12       /* EMM read word                */
#define EWW    13       /* WMM write word               */
#define VWW    14       /* Video write word             */
#define IRD    15       /* Instruction fetch, dword     */
#define MRD    16       /* RAM read dword               */
#define MWD    17       /* RAM write dword              */
#define RRD    18       /* ROM read dword               */
#define ERD    19       /* EMM read dword               */
#define EWD    20       /* EMM write dword              */
#define VWD    21       /* Video write dword            */
#define VARS88  3
#define VARS286 15
#define VARS386 22
/* Measurement procedures */
extern unsigned multime();
extern unsigned bclctime();
extern unsigned wmovtime();
extern unsigned dmovtime();
extern unsigned bdaatime();
extern unsigned bmvstime();
extern unsigned wmvstime();
extern unsigned dmvstime();
extern unsigned bromtime();
extern unsigned wromtime();
extern unsigned dromtime();
extern unsigned wpshtime();
extern unsigned dpshtime();
extern unsigned bemmtime();
extern unsigned wemptime();
```

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System requirements:

- 512K memory, DOS 2.0 or higher.
- Two double sided disk drives.*
- Graphics adapter card.

*hard disk recommended

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```
extern unsigned demptime();
extern unsigned wemmtime();
extern unsigned demmtime();
extern unsigned bvidtime();
extern unsigned wvidtime();
extern unsigned dvidtime();
extern unsigned fptime();
/* Timer rate in MHz */
#define TIMER2_RATE 1.193180
/* Number of processor clocks in a multiply instruction */
#define MULCLKS88 118
#define MULCLKS286 21
#define MULCLKS386 25
/* Overhead in the multiply test */
#define MULOVH88 ( 31 + 22*count/100 )
#define MULOVH286 ( 15 + 14*count/100 )
#define MULOVH386 ( 15 + 14*count/100 )
/* Overhead in the mov instruction test */
#define MOVOVH88 ( clktime * (31 + 22*count/100) )
#define MOVOVH286 ( clktime * (15 + 14*count/100) )
#define MOVOVH386 ( clktime * (15 + 14*count/100) )
/* Overhead in pusha instruction test */
#define WPOVH ( clktime * (15 + 9*count/200) )
#define DPOVH ( clktime * (15 + 9*count/200) )
/* Number of numeric processor clocks in a FP divide */
#define FPCLKS88 197
#define FPCLKS286 203
#define FPCLKS386 200
/* Processor overhead in the FP divide test */
#define FPOVH88 ( clktime * 2 * FPCOUNT )
#define FPOVH286 ( clktime * 9 * FPCOUNT )
#define FPOVH386 ( clktime * 9 * FPCOUNT )
/* Count for most tests */
#define COUNT 1000
/* Count for the f. p. divide test */
#define FPCOUNT 100
/* Number of trials for each test */
#define TRIALS 100
/* Variables which hold constants selected by cpu type */
int access_clks;
int cpu;        /* CPU type: 0=86/88,1=80186,2=80286,3=80386 */
double clkrate; /* Processor clock rate, MHz */
double clktime; /* Processor clock period, usec */
double fprate;  /* FP processor clock rate, MHz */
double fpacc;   /* FP processor clock period accumulator */
int emmok;      /* Set if extended memory is present */
int ndpok;      /* Set if math coprocessor is present */
int six;        /* Set if cpu is 8086 or 80186 */
double raw;     /* Variable for raw data */
double acctime[VARS386];   /* Accumulators for speeds */
int count;              /* Number of ops per trial */
int trials;             /* Number of repetitions */
/* Main program. */
main(argc, argv)
        int     argc;
        char    **argv;
{
        register int i;
        count = COUNT;
        trials = TRIALS;
/* Determine whether there a math coprocessor in the system. */
        ndpok = ndp_present();
/* Determine whether there is extended memory in the system and
 * allocate a piece of it for testing. */
        emmok = (setup_emm() == 0);
/* Detect the type of video card and save the information for the
 * video measurements. */
        setup_video();
/* Find out the CPU type and set parameters accordingly. */
        cpu = cpu_type();
        six = 0;
        switch (cpu) {
        case 0:
        case 1:
                access_clks = 4;
                measure88();
                break;
        case 2:
                access_clks = 2;
                measure286();
                break;
        case 3:
                access_clks = 2;
                measure386();
                break;
        default:
                printf("\nThis version of ATPERF is for ");
                printf("8088/86/188/186/286/386");
                printf("-based machines only.\n");
                exit(1);
        }
/* Release EMM memory page. */
        if (emmok)
                finish_emm();
/* Display the basic measurement results and performance index
 * relative to a 8 MHz AT. */
        printf("\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n\n");
        printf("ATPERF -- PC Tech Journal AT Hardware ");
        printf("Performance Test\n");
        printf("Version 2.00, Copyright (c) 1986, 1987, Ziff ");
        printf("Communications Co.\n");
        printf("Written by Ted Forgeron and Paul Pierce\n");
        printf("IBM PC/AT model 339 (8 MHz) = 1.00 for relative ");
        printf("measurements.\n");
        if (cpu < 2)
                printf("\n");
        printf("                                ");
        printf("    Byte         Word         ");
        if (cpu > 2)
                printf("Dword    ");
        printf("Relative\n");
        printf("Average instruction fetch:");
        printf("%#10.2g uS", acctime[IRB]);
        printf("%#10.2g uS", acctime[IRW]);
        if (cpu > 2)
                printf("%#10.2g uS", acctime[IRD]);
        printf("%#10.2g\n", 0.403/acctime[IRW]);
        if (cpu < 2) {
                printf("\n");
        } else {
                printf("Average RAM read time:    ");
                printf("%#10.2g uS", acctime[MRB]);
                printf("%#10.2g uS", acctime[MRW]);
                if (cpu > 2)
                        printf("%#10.2g uS", acctime[MRD]);
                printf("%#10.2g\n", 0.401/acctime[MRW]);
                printf("Average RAM write time:   ");
                printf("%#10.2g uS", acctime[MWB]);
                printf("%#10.2g uS", acctime[MWW]);
                if (cpu > 2)
                        printf("%#10.2g uS", acctime[MWD]);
                printf("%#10.2g\n", 0.401/acctime[MWW]);
                if (emmok) {
                        printf("Average EMM read time:    ");
                        printf("%#10.2g uS", acctime[ERB]);
                        printf("%#10.2g uS", acctime[ERW]);
                        if (cpu > 2)
                                printf("%#10.2g uS", acctime[ERD]);
                        printf("%#10.2g\n", 0.402/acctime[ERW]);
                        printf("Average EMM write time:   ");
                        printf("%#10.2g uS", acctime[EWB]);
                        printf("%#10.2g uS", acctime[EWW]);
                        if (cpu > 2)
                                printf("%#10.2g uS", acctime[EWD]);
                        printf("%#10.2g\n", 0.402/acctime[EWW]);
                }
                printf("Average ROM read time:    ");
                printf("%#10.2g uS", acctime[RRB]);
                printf("%#10.2g uS", acctime[RRW]);
                if (cpu > 2)
                        printf("%#10.2g uS", acctime[RRD]);
                printf("%#10.2g\n", 0.401/acctime[RRW]);
                printf("Average Video write time: ");
                printf("%#10.2g uS", acctime[VWB]);
                printf("%#10.2g uS", acctime[VWW]);
                if (cpu > 2)
                        printf("%#10.2g uS", acctime[VWD]);
                printf("%#10.2g\n", 2.415/acctime[VWW]);
```

```
        }
        switch (cpu) {
        case 0:
                if (six)
                        printf(" 8086");
                else
                        printf(" 8088");
                break;
        case 1:
                if (six)
                        printf(" 80186");
                else
                        printf(" 80188");
                break;
        case 2:
                printf("80286");
                break;
        case 3:
                printf("80386");
                break;
        }
        printf(" CPU clock rate:        ");
        printf("%#4.1g MHz", clkrate);
        printf("  Relative: %#4.2g\n", clkrate/8.0);
        if (ndpok) {
                printf("Math Coprocessor clock rate: ");
                printf("%#4.1g MHz", fprate);
                printf("  Relative: %#4.2g\n", fprate/5.33);
        }
 /* Calculate refresh overhead from instruction fetch time by assuming
  * that each fetch takes an exact multiple of the clock period.  The
  * difference between average time and the time for an individual
  * fetch is due to memory refresh cycles. */
        raw = acctime[IRW] / clktime;
        printf("Refresh overhead:           %#2.1g%%\n",
                ( (raw - (int)raw) / (int)raw ) * 100);
 /* Print information about memory based on the speed measurements. */
        printf("\nMemory   ");
        printf("       Access width          Wait states\n");
        if (cpu < 2) {
                if (six)
                        analyze("Fetch   ", acctime[IRW],
                                acctime[IRW], 2.0*acctime[IRW]);
                else
                        analyze("Fetch   ", acctime[IRB],
                                acctime[IRW], 2.0*acctime[IRW]);
        } else {
                analyze("RAM read ",
                        acctime[MRB], acctime[MRW], acctime[MRD]);
                analyze("RAM write",
                        acctime[MWB], acctime[MWW], acctime[MWD]);
                if (emmok) {
                        analyze("EMM read",
                         acctime[ERB], acctime[ERW], acctime[ERD]);
                        analyze("EMM write",
                         acctime[EWB], acctime[EWW], acctime[EWD]);
                }
                analyze("ROM read",
                        acctime[RRB], acctime[RRW], acctime[RRD]);
                analyze("Video write",
                        acctime[VWB], acctime[VWW], acctime[VWD]);
        }
}
measure88()
{
        register int i;
 /* Measure the clock rate by executing multiply instructions.  Each
  * multiply takes a fixed number of clock cycles. */
        clktime = 0;
        for (i = 0; i < trials; i++) {
 /* Obtain the number of clock ticks for "count" multiplies. */
                raw = multime(count);
 /* Accumulate the clock time in microseconds by adjusting for the
  * timer rate, number of clocks per multiply, instruction count, and
  * test overhead. */
                clktime +=  raw / (TIMER2_RATE *
                        ((double)MULCLKS88*count + MULOVH88));
        }
 /* Calculate the average clock period by dividing by the number of
  * trials.  The clock rate is the inverse of the clock period. */
        clktime /= trials;
        clkrate = 1.0/clktime;
 /* Clear all of the memory speed accumulators. */
        for (i = 0; i < VARS88; i++)
                acctime[i] = 0;
 /* Do the memory speed tests. */
        for (i = 0; i < trials; i++) {
 /* Obtain the number of timer ticks for "count" clc instructions,
  * which are limited by memory fetch time. */
                raw = bclctime(count);
 /* Accumulate the number of microseconds per instruction fetch by
  * adjusting for the timer rate, test overhead, and instruction
  * count. */
                acctime[IRB] +=
                        (raw / TIMER2_RATE - MOVOVH88) / count;
 /* Make a similar measurement for the two byte "mov" instruction. */
                raw = wmovtime(count);
                acctime[IRW] +=
                        (raw / TIMER2_RATE - MOVOVH88) / count;
 /* Make a similar measurement for the 4 clock "daa" instruction. */
                raw = bdaatime(count);
                acctime[IRX] +=
                        (raw / TIMER2_RATE - MOVOVH88) / count;
        }
 /* Calculate averages for all measurements. */
        for (i = 0; i < VARS88; i++)
                acctime[i] /= trials;
 /* Calculate numeric processor clock rate using floating point divide
  * instructions, using the same technique as was used to measure
  * the processor clock rate. */
        if (ndpok) {
                fprate = 0;
                for (i = 0; i < trials; i++) {
                        raw = fptime(FPCOUNT);
                        fpacc +=  (raw / TIMER2_RATE - FPOVH88) /
                                FPCLKS88 / FPCOUNT;
                }
                fpacc /= trials;
                fprate = 1.0/fpacc;
        }
 /* Set 86 flag if 2 clock byte instructions execute faster than 4
  * clock instructions due to being fetched two to a word. */
        six = acctime[IRB] < 0.9*acctime[IRX];
}
measure286()
{
        register int i;
 /* Measure the clock rate by executing multiply instructions.  Each
  * multiply takes a fixed number of clock cycles. */
        clktime = 0;
        for (i = 0; i < trials; i++) {
 /* Obtain the number of clock ticks for "count" multiplies. */
                raw = multime(count);
 /* Accumulate the clock time in microseconds by adjusting for the
  * timer rate, number of clocks per multiply, instruction count, and
  * test overhead. */
                clktime +=  raw / (TIMER2_RATE *
                        ((double)MULCLKS286*count + MULOVH286));
        }
 /* Calculate the average clock period by dividing by the number of
  * trials.  The clock rate is the inverse of the clock period. */
        clktime /= trials;
        clkrate = 1.0/clktime;
 /* Clear all of the memory speed accumulators. */
        for (i = 0; i < VARS286; i++)
                acctime[i] = 0;
 /* Do the memory speed tests. */
        for (i = 0; i < trials; i++) {
 /* Obtain the number of timer ticks for "count" clc instructions,
  * which are limited by memory fetch time. */
                raw = bclctime(count);
 /* Accumulate the number of microseconds per instruction fetch by
  * adjusting for timer rate, test overhead, and instruction count. */
                acctime[IRB] +=
                        (raw / TIMER2_RATE - MOVOVH286) / count;
 /* Make a similar measurement for the two byte "mov" instruction. */
                raw = wmovtime(count);
                acctime[IRW] +=
```

```
                        (raw / TIMER2_RATE - MOVOVH286) / count;
/* Measure byte read+write time measuring movs instructions. */
                raw = bmvstime(count);
                acctime[MRB] += raw/(TIMER2_RATE*count);
/* Calculate ROM read time by measuring movs from ROM to RAM. */
                raw = bromtime(count);
                acctime[RRB] += raw/(TIMER2_RATE*count);
/* Measure word write using the pusha instruction. */
                raw = wpshtime(count) - WPOVH;
                acctime[MWW] += raw/(TIMER2_RATE*count);
/* Measure movs (read+write) time. */
                raw = wmvstime(count);
                acctime[MRW] += raw/(TIMER2_RATE*count);
                raw = wromtime(count);
                acctime[RRW] += raw/(TIMER2_RATE*count);
/* If EMM is present, do measurements on it using same techniques. */
                if (emmok) {
/* Measure byte mov in EMM. */
                        raw = bemmtime(count);
                        acctime[ERB] += raw/(TIMER2_RATE*count);
/* Measure word write, calculate word read. */
                        raw = wemptime(count) - WPOVH;
                        acctime[EWW] += raw/(TIMER2_RATE*count);
                        raw = wemmtime(count);
                        acctime[ERW] += raw/(TIMER2_RATE*count);
                }
/* Measure byte and word writes into video RAM. */
                raw = bvidtime(count);
                acctime[VWB] += raw/(TIMER2_RATE*count);
                raw = wvidtime(count);
                acctime[VWW] += raw/(TIMER2_RATE*count);
        }
/* Calculate averages for all measurements. */
        for (i = 0; i < VARS286; i++)
                acctime[i] /= trials;
/* Adjust word write times by subtracting instruction fetch time. */
        acctime[MWW] -= acctime[IRW]/16;
        if (emmok)
                acctime[EWW] -= acctime[IRW]/16;
/* Adjust for extra time per instruction when measuring zero wait
 * state memory. */
        if (acctime[MWW] < 3.375*clktime)
                acctime[MWW] -= clktime/8;
        if (emmok)
                if (acctime[EWW] < 3.375*clktime)
                        acctime[EWW] -= clktime/8;
/* Calculate byte write time by assuming the same ratio between read
 * and write as for word access. */
        acctime[MWB] = acctime[MRB] * acctime[MWW] /
                       acctime[MRW];
        if (emmok)
                acctime[EWB] = acctime[ERB] * acctime[EWW] /
                               acctime[ERW];
/* Calculate read times by subtracting write time from
 * mov (read+write) time. */
        acctime[MRB] = acctime[MRB] - acctime[MWB];
        acctime[MRW] = acctime[MRW] - acctime[MWW];
        acctime[RRB] = acctime[RRB] - acctime[MWB];
        acctime[RRW] = acctime[RRW] - acctime[MWW];
        if (emmok) {
                acctime[ERB] = acctime[ERB] - acctime[EWB];
                acctime[ERW] = acctime[ERW] - acctime[EWW];
        }
/* Calculate numeric processor clock rate using floating point divide
 * instructions, using the same technique as was used to measure the
 * processor clock rate. */
        if (ndpok) {
                fprate = 0;
                for (i = 0; i < trials; i++) {
                        raw = fptime(FPCOUNT);
                        fpacc +=  (raw / TIMER2_RATE - FPOVH286) /
                                FPCLKS286 / FPCOUNT;
                }
                fpacc /= trials;
                fprate = 1.0/fpacc;
        }
/* Fill in dword variables to provide complete input to analyze. */
        acctime[MRD] = 2.0 * acctime[MRW];
        acctime[MWD] = 2.0 * acctime[MWW];
        acctime[ERD] = 2.0 * acctime[ERW];
        acctime[EWD] = 2.0 * acctime[EWW];
        acctime[RRD] = 2.0 * acctime[RRW];
        acctime[VWD] = 2.0 * acctime[VWW];
}
measure386()
{
        register int i;
/* Measure the clock rate by executing multiply instructions.  Each
 * multiply takes a fixed number of clock cycles. */
        clktime = 0;
        for (i = 0; i < trials; i++) {
/* Obtain the number of clock ticks for "count" multiplies. */
                raw = multime(count);
/* Accumulate the clock time in microseconds by adjusting for the
 * timer rate, number of clocks per multiply, instruction count, and
 * test overhead. */
                clktime +=  raw / (TIMER2_RATE *
                        ((double)MULCLKS386*count + MULOVH386));
        }
/* Calculate the average clock period by dividing by the number of
 * trials.  The clock rate is the inverse of the clock period. */
        clktime /= trials;
        clkrate = 1.0/clktime;
/* Clear all of the memory speed accumulators. */
        for (i = 0; i < VARS386; i++)
                acctime[i] = 0;
/* Do the memory speed tests. */
        for (i = 0; i < trials; i++) {
/* Obtain the number of timer ticks for "count" clc instructions,
 * which are limited by memory fetch time. */
                raw = bclctime(count);
/* Accumulate the number of microseconds per instruction fetch by
 * adjusting for timer rate, test overhead, and instruction count. */
                acctime[IRB] +=
                        (raw / TIMER2_RATE - MOVOVH386) / count;
/* Make a similar measurement for the two byte and four byte "mov"
 * instruction. */
                raw = wmovtime(count);
                acctime[IRW] +=
                        (raw / TIMER2_RATE - MOVOVH386) / count;
                raw = dmovtime(count);
                acctime[IRD] +=
                        (raw / TIMER2_RATE - MOVOVH386) / count;
/* Measure byte read+write time measuring movs instructions. */
                raw = bmvstime(count);
                acctime[MRB] += raw/(TIMER2_RATE*count);
/* Calculate ROM read time by measuring movs from ROM to RAM. */
                raw = bromtime(count);
                acctime[RRB] += raw/(TIMER2_RATE*count);
/* Measure word and dword write using the pusha instruction. */
                raw = wpshtime(count) - WPOVH;
                acctime[MWW] += raw/(TIMER2_RATE*count);
                raw = dpshtime(count) - DPOVH;
                acctime[MWD] += raw/(TIMER2_RATE*count);
/* Measure word and dword movs (read+write) time. */
                raw = wmvstime(count);
                acctime[MRW] += raw/(TIMER2_RATE*count);
                raw = wromtime(count);
                acctime[RRW] += raw/(TIMER2_RATE*count);
                raw = dmvstime(count);
                acctime[MRD] += raw/(TIMER2_RATE*count);
                raw = dromtime(count);
                acctime[RRD] += raw/(TIMER2_RATE*count);
/* If EMM is present, do measurements on it using same techniques. */
                if (emmok) {
                        raw = bemmtime(count);
                        acctime[ERB] += raw/(TIMER2_RATE*count);
                        raw = wemptime(count) - WPOVH;
                        acctime[EWW] += raw/(TIMER2_RATE*count);
                        raw = wemmtime(count);
                        acctime[ERW] += raw/(TIMER2_RATE*count);
                        raw = demptime(count) - DPOVH;
                        acctime[EWD] += raw/(TIMER2_RATE*count);
                        raw = demmtime(count);
                        acctime[ERD] += raw/(TIMER2_RATE*count);
                }
/* Measure writes into video RAM. */
                raw = bvidtime(count);
```

```
                acctime[VWB] += raw/(TIMER2_RATE*count);
                raw = wvidtime(count);
                acctime[VWW] += raw/(TIMER2_RATE*count);
                raw = dvidtime(count);
                acctime[VWD] += raw/(TIMER2_RATE*count);
        }
/* Calculate averages for all measurements. */
        for (i = 0; i < VARS386; i++)
                acctime[i] /= trials;
/* Adjust word write times by subtracting instruction fetch time. */
        acctime[MWW] -= acctime[IRW]/16;
        acctime[MWD] -= acctime[IRW]/8;
        if (emmok) {
                acctime[EWW] -= acctime[IRW]/16;
                acctime[EWD] -= acctime[IRW]/8;
        }
/* Adjust for extra time per instruction when measuring zero wait
 * state memory. */
        if (acctime[MWW] < 3.375*clktime)
                acctime[MWW] -= clktime;
        if (acctime[MWD] < 3.375*clktime)
                acctime[MWD] -= clktime;
        if (emmok) {
                if (acctime[EWW] < 3.375*clktime)
                        acctime[EWW] -= clktime;
                if (acctime[EWD] < 3.375*clktime)
                        acctime[EWD] -= clktime;
        }
/* Calculate byte write time by assuming the same ratio between read
 * and write as for word access. */
        acctime[MWB] = acctime[MRB] * acctime[MWW] /
                       acctime[MRW];
        if (emmok)
                acctime[EWB] = acctime[ERB] * acctime[EWW] /
                               acctime[ERW];
/* Calculate read times by subtracting write time from
 * mov (read+write) time. */
        acctime[MRB] = acctime[MRB] - acctime[MWB];
        acctime[MRW] = acctime[MRW] - acctime[MWW];
        acctime[MRD] = acctime[MRD] - acctime[MWD];
        acctime[RRB] = acctime[RRB] - acctime[MWB];
        acctime[RRW] = acctime[RRW] - acctime[MWW];
        acctime[RRD] = acctime[RRD] - acctime[MWD];
        if (emmok) {
                acctime[ERB] = acctime[ERB] - acctime[EWB];
                acctime[ERW] = acctime[ERW] - acctime[EWW];
                acctime[ERD] = acctime[ERD] - acctime[EWD];
        }
/* Calculate numeric processor clock rate using floating point divide
 * instructions, using the same technique as was used to measure the
 * processor clock rate. */
        if (ndpok) {
                fprate = 0;
                for (i = 0; i < trials; i++) {
                        raw = fptime(FPCOUNT);
                        fpacc +=  (raw / TIMER2_RATE - FPOVH386) /
                                FPCLKS386 / FPCOUNT;
                }
                fpacc /= trials;
                fprate = 1.0/fpacc;
        }
}
/* analyze. This procedure deduces information about the memory based
 * on the measured times. If byte (8 bits) and word (16 bits) times
 * are different then the memory is byte oriented since each word
 * operation takes two byte operations.  Otherwise, if the byte and
 * word times are about the same, the memory is word oriented and can
 * access either a word or a byte in a single memory cycle.
 * Similar arguments can be made about 32 bit accesses.
 * Each memory access takes an exact number of processor clock
 * cycles.  The first two are required by the processor, but
 * any additional cycles are determined by the memory and are
 * called wait states (because the processor is waiting for
 * the memory.) */
analyze(name, btime, wtime, dtime)
        char    *name;
        double  btime;
        double  wtime;
        double  dtime;
{
        double  t;
/* Print the heading */
        printf("%-12s", name);
/* Determine whether the memory is byte oriented, word oriented, dword
 * oriented, or other. (If other, the data are suspect.) */
        if (wtime > dtime*0.66 &&
            wtime < dtime*1.33) {
                printf("        Dword ");
                t = dtime;
        } else if (wtime*2 > dtime*0.66 &&
                   wtime*2 < dtime*1.33 &&
                   btime > wtime*0.66 &&
                   btime < wtime*1.33) {
                printf("        Word  ");
                t = wtime;
        } else if (btime*2 > wtime*0.66 &&
                   btime*2 < wtime*1.33) {
                printf("        Byte  ");
                t = btime;
        } else {
                printf("      Strange");
                t = btime;
        }
/* Determine the number of wait states by dividing by the clock
 * period, subtracting two processor clock times, and rounding down
 * to an integer. */
        t = t / clktime - access_clks;
        if (t < 0.0)
                t = 0.0;
        printf("             %6d\n", (unsigned)t);
}
```

LISTING 2: TIME.ASM

```
                NAME    TIME

_TEXT   SEGMENT  PARA PUBLIC 'CODE'
_TEXT   ENDS
CONST   SEGMENT  PARA PUBLIC 'CONST'
CONST   ENDS
_BSS    SEGMENT  PARA PUBLIC 'BSS'
_BSS    ENDS
_DATA   SEGMENT  PARA PUBLIC 'DATA'
_DATA   ENDS
DGROUP  GROUP   CONST,  _BSS,   _DATA
        ASSUME  CS: _TEXT, DS: DGROUP, SS: DGROUP, ES: DGROUP
TESTSEG SEGMENT PARA PUBLIC 'TEST'
TESTSEG_START   DW      32767 DUP (?)
TESTSEG ENDS
PPI_PORT        EQU     061H
TIMER2_PORT     EQU     042H
TIMER_CTRL      EQU     043H
_DATA           SEGMENT
VIDBASE         DW      0B800H
EMMBASE         DW      9000H
PID             DW      ?
EMM_NAME        DB      "EMMXXXX0"
_DATA           ENDS
_TEXT           SEGMENT
;*************************************************************;
;       _MULTIME                                              ;
;       TIME EXECUTION OF MULTIPLY INSTRUCTIONS               ;
;*************************************************************;
        EVEN
        DB      ?, ?
                PUBLIC  _MULTIME
_MULTIME        PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, 08000H              ; SET DI
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        ADD     AX, 99                  ; ROUND UP
        MOV     CX, 100                 ; DIVIDE BY 100 =
        DIV     CL                      ;  NUMBER OF INSTRUCTIONS
        MOV     CL, AL                  ;  PER PASS
        NOP                             ; ALIGN INSTRUCTIONS
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
```

```
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
ML:     REPT    100                     ; DO 100 MULTIPLIES
        MUL     DI                      ;
        ENDM                            ; END MACRO
        DEC     CX                      ; COUNT THIS PASS
        JZ      MD                      ; JUMP IF COMPLETE
        JMP     ML                      ; LOOP BACK IF NOT DONE
MD:     MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_MULTIME        ENDP
;*************************************************************;
;       _WMOVTIME                                             ;
;       TIME EXECUTION OF MOV INSTRUCTION (INSTR. READ TIME)    ;
;*************************************************************;
        EVEN
                PUBLIC  _WMOVTIME
_WMOVTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, 0                   ; CLEAR DI
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        ADD     AX, 99                  ; ROUND UP
        MOV     CX, 100                 ; DIVIDE BY 100 =
        DIV     CL                      ;  NUMBER OF INSTRUCTIONS
        MOV     CL, AL                  ;  PER PASS
        NOP                             ; ALIGN INSTRUCTIONS
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
IL:     REPT    100                     ; DO 100 MOVES
        MOV     DX, BX                  ;
        ENDM                            ; END MACRO
        DEC     CX                      ; COUNT THIS PASS
        JZ      ID                      ; JUMP IF COMPLETE
        JMP     IL                      ; LOOP BACK IF NOT DONE
ID:     MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_WMOVTIME       ENDP
;*************************************************************;
;       _DMOVTIME                                             ;
;       TIME EXECUTION OF MOV INSTRUCTION (INSTR. READ TIME)    ;
;*************************************************************;
        EVEN
        DB      ?, ?
        DB      0, 0
                PUBLIC  _DMOVTIME
_DMOVTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, 0                   ; CLEAR DI
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        ADD     AX, 99                  ; ROUND UP
        MOV     CX, 100                 ; DIVIDE BY 100 =
        DIV     CL                      ;  NUMBER OF INSTRUCTIONS
        MOV     CL, AL                  ;  PER PASS
        NOP                             ; ALIGN INSTRUCTIONS
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
NL:     REPT    100                     ; DO 100 MOV DX,05555H
        DB      0C7H, 0C2H, 055H, 055H  ;  THE LONG WAY (WITH MOD R/M)
        ENDM                            ; END MACRO
        DEC     CX                      ; COUNT THIS PASS
        JZ      ND                      ; JUMP IF COMPLETE
        JMP     NL                      ; LOOP BACK IF NOT DONE
ND:     MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_DMOVTIME       ENDP
;*************************************************************;
;       _BCLCTIME                                             ;
;       TIME EXECUTION OF CLC INSTRUCTION (INSTR. READ TIME)    ;
;*************************************************************;
        EVEN
                PUBLIC  _BCLCTIME
_BCLCTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, 0                   ; CLEAR DI
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        ADD     AX, 99                  ; ROUND UP
        MOV     CX, 100                 ; DIVIDE BY 100 =
        DIV     CL                      ;  NUMBER OF INSTRUCTIONS
        MOV     CL, AL                  ;  PER PASS
        NOP                             ; ALIGN INSTRUCTIONS
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
BIL:    REPT    100                     ; DO 100 CLC'S
        CLC                             ;
        ENDM                            ; END MACRO
        DEC     CX                      ; COUNT THIS PASS
        JZ      BID                     ; JUMP IF COMPLETE
        JMP     BIL                     ; LOOP BACK IF NOT DONE
BID:    MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_BCLCTIME       ENDP
;*************************************************************;
;       _BDAATIME                                             ;
;       TIME EXECUTION OF DAA INSTRUCTION (INSTR. READ TIME)    ;
;*************************************************************;
        EVEN
        DB      ?, ?
                PUBLIC  _BDAATIME
_BDAATIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, 0                   ; CLEAR DI
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        ADD     AX, 99                  ; ROUND UP
        MOV     CX, 100                 ; DIVIDE BY 100 =
        DIV     CL                      ;  NUMBER OF INSTRUCTIONS
        MOV     CL, AL                  ;  PER PASS
        NOP                             ; ALIGN INSTRUCTIONS
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
BXL:    REPT    100                     ; DO 100 DAA'S
        DAA                             ;
        ENDM                            ; END MACRO
        DEC     CX                      ; COUNT THIS PASS
        JZ      BXD                     ; JUMP IF COMPLETE
```

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```
        JMP     BXL                     ; LOOP BACK IF NOT DONE
BXD:    MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_BDAATIME       ENDP
;*************************************************************;
;       _BMVSTIME                                             ;
;       TIME EXECUTION OF REP MOVSB INSTRUCTION               ;
;*************************************************************;
                PUBLIC  _BMVSTIME
_BMVSTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, TESTSEG             ;
        MOV     ES, DI                  ;
        MOV     DS, DI                  ;
        LEA     SI, TESTSEG_START       ; DS:SI -> TEST SEGMENT
        LEA     DI, TESTSEG_START       ; ES:DI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP MOVSB                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_BMVSTIME       ENDP
;*************************************************************;
;       _WMVSTIME                                             ;
;       TIME EXECUTION OF REP MOVSW INSTRUCTION               ;
;*************************************************************;
                PUBLIC  _WMVSTIME
_WMVSTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, TESTSEG             ;
        MOV     ES, DI                  ;
        MOV     DS, DI                  ;
        LEA     SI, TESTSEG_START       ; DS:SI -> TEST SEGMENT
        LEA     DI, TESTSEG_START       ; ES:DI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP MOVSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_WMVSTIME       ENDP
;*************************************************************;
;       _DMVSTIME                                             ;
;       TIME EXECUTION OF REP MOVSW INSTRUCTION               ;
;*************************************************************;
                PUBLIC  _DMVSTIME
_DMVSTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     DI, DI                  ; CLEAR EDI
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     SI, SI                  ; CLEAR ESI
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     CX, CX                  ; CLEAR ECX
        MOV     DI, TESTSEG             ;
        MOV     ES, DI                  ;
        MOV     DS, DI                  ;
        LEA     SI, TESTSEG_START       ; DS:SI -> TEST SEGMENT
        LEA     DI, TESTSEG_START       ; ES:DI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        REP MOVSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_DMVSTIME       ENDP
;*************************************************************;
;       _WPSHTIME                                             ;
;       TIME EXECUTION OF PUSHA INSTRUCTION                   ;
;*************************************************************;
        EVEN
        DB      ?
                PUBLIC  _WPSHTIME
_WPSHTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        CWD                             ; MAKE DOUBLE WORD
        MOV     CX, 200                 ;
        DIV     CX                      ; DIVIDE BY MOVS/LOOP
        MOV     CX, AX                  ;
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
WSL:    REPT    25                      ; PUSH THE REGISTERS
        DB      60H                     ;
        ENDM                            ; END MACRO
        MOV     SP, BP                  ; PUT THE STACK BACK
        LOOP    WSL                     ; LOOP UNTIL DONE
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        MOV     SP, BP                  ; PUT THE STACK BACK
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
```

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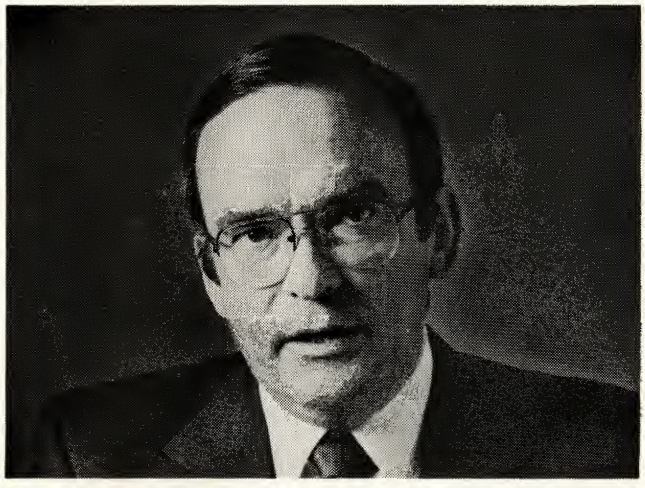

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```
_WPSHTIME       ENDP
;*************************************************************;
;       _DPSHTIME                                             ;
;       TIME EXECUTION OF PUSHA INSTRUCTION                   ;
;*************************************************************;
        EVEN
        DB      ?, ?, ?
                PUBLIC  _DPSHTIME
_DPSHTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        CWD                             ; MAKE DOUBLE WORD
        MOV     CX, 200                 ;
        DIV     CX                      ; DIVIDE BY MOVS/LOOP
        MOV     CX, AX                  ;
        AND     SP, OFFFCH              ; ALIGN SP
        PUSH    AX                      ; DUMMY
        PUSH    BP                      ; SAVE BP
        MOV     BP, SP                  ;
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
DSL:    REPT    25                      ; PUSH THE BIG REGISTERS
        DB      66H, 60H                ;
        ENDM                            ; END MACRO
        MOV     SP, BP                  ; PUT THE STACK BACK
        LOOP    DSL                     ; LOOP UNTIL DONE
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        POP     BP                      ;
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        MOV     SP, BP                  ; PUT THE STACK BACK
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_DPSHTIME       ENDP
;*************************************************************;
;       _BROMTIME                                             ;
;       TIME EXECUTION OF REP MOVSB INSTRUCTION FROM ROM      ;
;*************************************************************;
                PUBLIC  _BROMTIME
_BROMTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, TESTSEG             ;
        MOV     ES, DI                  ;
        MOV     DI, 0F000H              ; SET DS TO ROM START
        MOV     DS, DI                  ;
        MOV     SI, 0                   ; DS:SI -> ROM
        LEA     DI, TESTSEG_START       ; ES:DI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP MOVSB                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_BROMTIME       ENDP
```

```
;*************************************************************;
;       _WROMTIME                                             ;
;       TIME EXECUTION OF REP MOVSW INSTRUCTION FROM ROM      ;
;*************************************************************;
                PUBLIC  _WROMTIME
_WROMTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, TESTSEG             ;
        MOV     ES, DI                  ;
        MOV     DI, 0F000H              ; SET DS TO ROM START
        MOV     DS, DI                  ;
        MOV     SI, 0                   ; DS:SI -> ROM
        LEA     DI, TESTSEG_START       ; ES:DI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP MOVSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_WROMTIME       ENDP
;*************************************************************;
;       _DROMTIME                                             ;
;       TIME EXECUTION OF REP MOVSW INSTRUCTION FROM ROM      ;
;*************************************************************;
                PUBLIC  _DROMTIME
_DROMTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     DI, DI                  ; CLEAR EDI
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     SI, SI                  ; CLEAR ESI
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     CX, CX                  ; CLEAR ECX
        MOV     DI, TESTSEG             ;
        MOV     ES, DI                  ;
        MOV     DI, 0F000H              ; SET DS TO ROM START
        MOV     DS, DI                  ;
        MOV     SI, 0                   ; DS:SI -> ROM
        LEA     DI, TESTSEG_START       ; ES:DI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        REP MOVSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
```

```
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_DROMTIME       ENDP
;*************************************************************;
;       _BVIDTIME                                             ;
;       TIME EXECUTION OF REP STOSB INTO VIDEO MEMORY         ;
;*************************************************************;
                PUBLIC  _BVIDTIME
_BVIDTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    ES                      ; SAVE ES
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     AX, VIDBASE             ; GET BASE ADDRESS
        MOV     ES, AX                  ;
        MOV     DI, 0                   ; ES:DI -> VIDEO MEMORY
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP STOSB                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     ES                      ; RESTORE ES
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_BVIDTIME       ENDP
;*************************************************************;
;       _WVIDTIME                                             ;
;       TIME EXECUTION OF REP STOSW INTO VIDEO MEMORY         ;
;*************************************************************;
                PUBLIC  _WVIDTIME
_WVIDTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    ES                      ; SAVE ES
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     AX, VIDBASE             ; GET BASE ADDRESS
        MOV     ES, AX                  ;
        MOV     DI, 0                   ; ES:DI -> VIDEO MEMORY
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP STOSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     ES                      ; RESTORE ES
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_WVIDTIME       ENDP
;*************************************************************;
;       _DVIDTIME                                             ;
;       TIME EXECUTION OF REP STOSW INTO VIDEO MEMORY         ;
;*************************************************************;
                PUBLIC  _DVIDTIME
_DVIDTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    ES                      ; SAVE ES
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     DI, DI                  ; CLEAR EDI
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     CX, CX                  ; CLEAR ECX
        MOV     AX, VIDBASE             ; GET BASE ADDRESS
        MOV     ES, AX                  ;
        DB      066H                    ; 32 BIT OPERANDS:
        MOV     AX, 0700H               ;  MOV EAX, 07000700H
        DW      0700H                   ;
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        REP STOSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     ES                      ; RESTORE ES
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_DVIDTIME       ENDP
;*************************************************************;
;       _SETUP_VIDEO                                          ;
;       DETECT THE TYPE OF VIDEO CARD AND SAVE THE BASE       ;
;*************************************************************;
                PUBLIC  _SETUP_VIDEO
_SETUP_VIDEO    PROC    NEAR
        PUSH    BP                      ; SAVE REGISTERS
        PUSH    ES                      ;
        PUSH    SI                      ;
        PUSH    DI                      ;
        INT     11H                     ; EQUIPMENT DETERMINATION
        AND     AL, 30H                 ; MASK DISPLAY BITS
        CMP     AL, 30H                 ; CHECK FOR MONOCHROME
        MOV     AX, 0B000H              ; MONOCHROME BASE
        JE      SVM                     ; JUMP IF MONOCHROME
        MOV     AX, 0B800H              ; COLOR BASE
SVM:    MOV     VIDBASE, AX             ; SAVE BASE ADDRESS
        POP     DI                      ; RESTORE REGISTERS
        POP     SI                      ;
        POP     ES                      ;
        POP     BP                      ;
        RET                             ; RETURN 0
_SETUP_VIDEO    ENDP
;*************************************************************;
;       _FPTIME                                               ;
;       TIME EXECUTION OF FLOATING POINT DIVIDE               ;
;*************************************************************;
        EVEN
        DB      ?
                PUBLIC  _FPTIME
_FPTIME         PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, 0                   ; CLEAR DI
        MOV     AX, [BP+4]              ; GET COUNT ARGUMENT
        ADD     AX, 99                  ; ROUND UP
        MOV     CX, 100                 ; DIVIDE BY 100 =
        DIV     CL                      ;  NUMBER OF INSTRUCTIONS
        MOV     CL, AL                  ;  PER PASS
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        FNINIT                          ; INIT FP
        FLD1                            ; DIVIDE 1.0
        FLD1                            ; BY 1.0
        CLI                             ; STOP INTERRUPTS
        OUT     PPI_PORT, AL            ; ENABLE TIMER
FL:     REPT    100                     ; DO 100 DIVIDES
        FDIV    ST(1), ST               ;
        ENDM                            ; END MACRO
        DEC     CX                      ; COUNT THIS PASS
        JZ      FD                      ; JUMP IF COMPLETE
        JMP     FL                      ; LOOP BACK IF NOT DONE
```

```
FD:     MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_FPTIME         ENDP
;*************************************************************;
;       _WEMPTIME                                             ;
;       TIME EXECUTION OF PUSHA INSTRUCTION                   ;
;*************************************************************;
        EVEN
        DB      ?, ?, ?
                PUBLIC  _WEMPTIME
_WEMPTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        PUSH    DI                      ; SAVE DI
        MOV     BP, SP                  ;
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     AX, [BP+6]              ; GET COUNT ARGUMENT
        CWD                             ; MAKE DOUBLE WORD
        MOV     CX, 200                 ;
        DIV     CX                      ; DIVIDE BY MOVS/LOOP
        MOV     CX, AX                  ;
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        MOV     DX, SS                  ; SAVE STACK SEGMENT
        MOV     SS, EMMBASE             ; PUT STACK IN EMM
        MOV     SP, 400                 ; SET SP FOR PUSHES
        MOV     DI, SP                  ; SAVE THIS NUMBER
        OUT     PPI_PORT, AL            ; ENABLE TIMER
EPL:    REPT    25                      ; PUSH THE REGISTERS
        DB      60H                     ;
        ENDM                            ;
        MOV     SP, DI                  ; PUT THE STACK BACK
        LOOP    EPL                     ; LOOP UNTIL DONE
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        MOV     SS, DX                  ; RESTORE ORIGINAL STACK
        MOV     SP, BP                  ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_WEMPTIME       ENDP
;*************************************************************;
;       _DEMPTIME                                             ;
;       TIME EXECUTION OF PUSHA INSTRUCTION                   ;
;*************************************************************;
        EVEN
        DB      ?
                PUBLIC  _DEMPTIME
_DEMPTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        PUSH    DI                      ; SAVE DI
        MOV     BP, SP                  ;
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     AX, [BP+6]              ; GET COUNT ARGUMENT
        CWD                             ; MAKE DOUBLE WORD
        MOV     CX, 200                 ;
        DIV     CX                      ; DIVIDE BY MOVS/LOOP
        MOV     CX, AX                  ;
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        MOV     DX, SS                  ; SAVE STACK SEGMENT
        MOV     SS, EMMBASE             ; PUT STACK IN EMM
        MOV     SP, 800                 ; SET SP FOR PUSHES
        MOV     DI, SP                  ; SAVE THIS NUMBER
        OUT     PPI_PORT, AL            ; ENABLE TIMER
EDL:    REPT    25                      ; PUSH THE BIG REGISTERS
        DB      66H, 60H                ;
        ENDM                            ; END MACRO
        MOV     SP, DI                  ; PUT THE STACK BACK
        LOOP    EDL                     ; LOOP UNTIL DONE
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        MOV     SS, DX                  ; RESTORE ORIGINAL STACK
        MOV     SP, BP                  ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_DEMPTIME       ENDP
;*************************************************************;
;       _BEMMTIME                                             ;
;       TIME EXECUTION OF REP MOVSB INSTRUCTION               ;
;*************************************************************;
                PUBLIC  _BEMMTIME
_BEMMTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, EMMBASE             ; SET UP EMM BASE ADDRESS
        MOV     ES, DI                  ;
        MOV     DS, DI                  ;
        XOR     DI, DI                  ; ES:DI -> TEST SEGMENT
        XOR     SI, SI                  ; DS:SI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP MOVSB                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_BEMMTIME       ENDP
;*************************************************************;
;       _WEMMTIME                                             ;
;       TIME EXECUTION OF REP MOVSW INSTRUCTION               ;
;*************************************************************;
                PUBLIC  _WEMMTIME
_WEMMTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        MOV     DI, EMMBASE             ; SET UP EMM BASE ADDRESS
        MOV     ES, DI                  ;
        MOV     DS, DI                  ;
        XOR     DI, DI                  ; ES:DI -> TEST SEGMENT
        XOR     SI, SI                  ; DS:SI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        REP MOVSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
```

Version 3.0

New Features

Windows, Data Entry, Help Management, Menus, Text Editing, plus ...

SOURCE CODE

FREE

Vitamin C

It's good for your system!

The Vitamin C Difference

With **Vitamin C,** your applications come alive with windows that explode into view! Data entry windows and menus become a snap, and context sensitive pop-up help messages are nearly automatic.

With **VCScreen,** you'll save time by interactively painting windows and forms so what you see is what you get! Then, one button generates C source code ready to plug into your program and link with Vitamin C.

Easy enough for the beginner. Versatile enough for the professional. Vitamin C's **open-ended design** is full of "hooks" so you can intercept and "plug-in" special handlers to customize or add features to most routines.

Of course, Vitamin C **includes all source code FREE,** with no hidden charges. *It always has.* That means you'll have everything you need to adapt to special needs without spending hundreds of dollars more.

Windows

Create as many windows as you like with one easy function. Vitamin C automatically takes care of complicated tasks like saving and restoring the area under a window.

Options include titles, borders, colors, pop-up, pull-down, zoom-in, 4-way scrolling, scroll bars, sizes up to 32k, text file display & editing, cursor display, and more.

Unique built-in feature lets users move and resize windows during run-time via a definable key.

Access the current window by default or a specific window any time, even if it's hidden or invisible. Save and load windows on disk for more versatility!

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Vitamin C even provides true right-to-left input of numeric fields with dynamic display of separators & currency symbols.

High Level Functions

Use our intergrated help management, multi-level menus, and text file routines, or build your own handlers using Vitamin C's basic windowing and data entry routines.

Standard help handler provides context sensitive pop-up help messages any time the program awaits key strokes. The help text file is stored on disk and indexed for quick access. So easy to use that a single function initializes & services requests by opening a window, locating, formatting, displaying, and paging through the message.

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Text editor windows can be opened for pop-up note pads, memo fields, or general purpose editing. Features include insert, delete, word wrap, and paragraph formatting.

VCScreen

Screen Painter/Code Generator

Just as Vitamin C's reusable functions speed your programming, VCSreen makes it even *faster and easier* by automatically generating C source code for your data entry screens!

With VCScreen's interactive screen editor, you actually draw your forms. You can define input, output and constant fields, headings, boxes, lines and even a window for the form to run in.

What you see is what you get. If you don't like the position of an object, just "pick it up" with the cursor and move it! Changing colors, attributes, copying, and deleting is just as easy.

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```
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_WEMMTIME       ENDP
;*************************************************************;
;       _DEMMTIME                                             ;
;       TIME EXECUTION OF REP MOVSW INSTRUCTION               ;
;*************************************************************;
                PUBLIC  _DEMMTIME
_DEMMTIME       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSH    DS                      ; SAVE DS
        PUSH    ES                      ; SAVE ES
        PUSH    SI                      ; SAVE SI
        PUSH    DI                      ; SAVE DI
        CALL    SETUP_TIMER             ; SET UP TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     DI, DI                  ; CLEAR EDI
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     SI, SI                  ; CLEAR ESI
        DB      066H                    ; 32 BIT OPERANDS:
        XOR     CX, CX                  ; CLEAR ECX
        MOV     DI, EMMBASE             ; SET UP EMM BASE ADDRESS
        MOV     ES, DI                  ;
        MOV     DS, DI                  ;
        XOR     DI, DI                  ; ES:DI -> TEST SEGMENT
        XOR     SI, SI                  ; DS:SI -> TEST SEGMENT
        MOV     CX, [BP+4]              ; GET COUNT ARGUMENT
        IN      AL, PPI_PORT            ; GET CURRENT CONTROL
        MOV     BL, AL                  ; SAVE IN BL
        OR      AX, 1                   ; SET TIMER ENABLE BIT
        CLI                             ; STOP INTERRUPTS
        CLD                             ; SET FORWARD DIRECTION
        OUT     PPI_PORT, AL            ; ENABLE TIMER
        DB      066H                    ; 32 BIT OPERANDS:
        REP MOVSW                       ; RUN TEST
        MOV     AL, BL                  ; RESTORE CONTROL VALUE
        OUT     PPI_PORT, AL            ;
        STI                             ; START INTERRUPTS
        CALL    GET_TIMER               ; OBTAIN FINAL COUNT
        POP     DI                      ; RESTORE DI
        POP     SI                      ; RESTORE SI
        POP     ES                      ; RESTORE ES
        POP     DS                      ; RESTORE DS
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_DEMMTIME       ENDP
;*************************************************************;
;       _SETUP_EMM                                            ;
;       SET UP EXPANDED MEMORY AND RETURN THE BASE            ;
;*************************************************************;
                PUBLIC  _SETUP_EMM
_SETUP_EMM      PROC    NEAR
        PUSH    BP                      ; SAVE REGISTERS
        PUSH    ES                      ;
        PUSH    SI                      ;
        PUSH    DI                      ;
        MOV     AH, 35H                 ; GET EMM INTERRUPT
        MOV     AL, 67H                 ; VECTOR
        INT     21H                     ;
        MOV     AX, ES                  ; CHECK FOR VALID BASE
        MOV     BX, CS                  ; MUST BE BELOW CS
        CMP     AX, BX                  ;
        JA      SENO                    ; JUMP IF NOT GOOD
        MOV     DI, 000AH               ; OFFSET OF DRIVER NAME
        LEA     SI, EMM_NAME            ; COMPARE STRING
        MOV     CX, 8                   ; LENGTH OF STRING
        CLD                             ;
        REPE    CMPSB                   ; COMPARE THE NAME
        JNE     SENO                    ; JUMP IF NO GOOD
SE1:    MOV     AH, 40H                 ; FUNCTION 1:
        INT     67H                     ; GET MANAGER STATUS
        CMP     AH, 82H                 ; CHECK FOR BUSY
        JE      SE1                     ; TRY AGAIN IF BUSY
        OR      AH, AH                  ; CHECK FOR ERROR
        JNZ     SENO                    ; JUMP ON ERROR
SE2:    MOV     AH, 41H                 ; FUNCTION 2:
        INT     67H                     ; GET PAGE FRAME BASE
        CMP     AH, 82H                 ; CHECK FOR BUSY
        JE      SE2                     ; TRY AGAIN IF BUSY
        OR      AH, AH                  ; CHECK FOR ERROR
        JNZ     SENO                    ; JUMP ON ERROR
        MOV     EMMBASE, BX             ; SAVE THE BASE
SE3:    MOV     AH, 42H                 ; FUNCTION 3:
        INT     67H                     ; GET NUMBER OF PAGES
        CMP     AH, 82H                 ; CHECK FOR BUSY
        JE      SE3                     ; TRY AGAIN IF BUSY
        OR      AH, AH                  ; CHECK FOR ERROR
        JNZ     SENO                    ; JUMP ON ERROR
        OR      BX, BX                  ; CHECK UNALLOCATED PAGES
        JZ      SENO                    ; JUMP IF NONE AVAILABLE
SE4:    MOV     AH, 43H                 ; FUNCTION 4:
        MOV     BX, 1                   ; ALLOCATE ONE PAGE
        INT     67H                     ;
        CMP     AH, 82H                 ; CHECK FOR BUSY
        JE      SE4                     ; TRY AGAIN IF BUSY
        OR      AH, AH                  ; CHECK FOR ERROR
        JNZ     SENO                    ; JUMP ON ERROR
        MOV     PID, DX                 ; SAVE THE PROCESS ID
SE5:    MOV     AH, 44H                 ; FUNCTION 5:
        XOR     BX, BX                  ; MAP THE PAGE TO
        XOR     AL, AL                  ;  FRAME BASE
        INT     67H                     ;
        CMP     AH, 82H                 ; CHECK FOR BUSY
        JE      SE5                     ; TRY AGAIN IF BUSY
        OR      AH, AH                  ; CHECK FOR ERROR
        JNZ     SENC                    ; JUMP ON ERROR
        XOR     AX, AX                  ;
        POP     DI                      ; RESTORE REGISTERS
        POP     SI                      ;
        POP     ES                      ;
        POP     BP                      ;
        RET                             ; RETURN 0
SENC:   MOV     AH, 45H                 ; FUNCTION 6:
        INT     67H                     ; CLOSE EMM
        CMP     AH, 82H                 ; CHECK FOR BUSY
        JE      SENC                    ; TRY AGAIN IF BUSY
SENO:   MOV     AX, 0FFFFH              ;
        POP     DI                      ; RESTORE REGISTERS
        POP     SI                      ;
        POP     ES                      ;
        POP     BP                      ;
        RET                             ; RETURN -1
_SETUP_EMM      ENDP
;*************************************************************;
;       _FINISH_EMM                                           ;
;       CLOSE THE EMM DEVICE, RELEASE THE PAGE                ;
;*************************************************************;
                PUBLIC  _FINISH_EMM
_FINISH_EMM     PROC    NEAR
        PUSH    BP                      ; SAVE REGISTERS
        PUSH    ES                      ;
        PUSH    SI                      ;
        PUSH    DI                      ;
SE6:    MOV     AH, 45H                 ; FUNCTION 6:
        MOV     DX, PID                 ; CLOSE EMM
        INT     67H                     ;
        CMP     AH, 82H                 ; CHECK FOR BUSY
        JE      SE6                     ; TRY AGAIN IF BUSY
        POP     DI                      ; RESTORE REGISTERS
        POP     SI                      ;
        POP     ES                      ;
        POP     BP                      ;
        RET                             ; RETURN
_FINISH_EMM     ENDP
;*************************************************************;
;       SETUP_TIMER                                           ;
;       SET UP THE TIMER FOR MAXIMUM COUNT, TO TIME A RUN     ;
;*************************************************************;
SETUP_TIMER     PROC    NEAR
        PUSH    AX                      ; SAVE AX
        IN      AL, PPI_PORT            ; STOP THE TIMER
        AND     AL, 0FCH                ;
        OUT     PPI_PORT, AL            ;
        MOV     AL, 0B4H                ; INITIALIZE THE TIMER
        OUT     TIMER_CTRL, AL          ;
        MOV     AL, 0                   ; CLEAR THE COUNT
        OUT     TIMER2_PORT, AL         ;
        NOP                             ;
```

```
        OUT     TIMER2_PORT, AL         ;
        POP     AX                      ; RESTORE AX
        RET                             ; RETURN
SETUP_TIMER     ENDP
;*************************************************************;
;       GET_TIMER                                             ;
;       TAKE THE COUNT FROM THE TIMER                         ;
;*************************************************************;
GET_TIMER       PROC    NEAR
        PUSH    BX                      ; SAVE REGISTERS
        IN      AL, TIMER2_PORT         ; GET LOW BYTE OF TIME
        MOV     AH, AL                  ;
        IN      AL, TIMER2_PORT         ; GET HIGH BYTE
        XCHG    AL, AH                  ; TIME IN AX
        NEG     AX                      ; CORRECT FOR COUNT-DOWN
        POP     BX                      ; RESTORE REGISTERS
        RET                             ; RETURN
GET_TIMER       ENDP
;*************************************************************;
;       _NDP_PRESENT                                          ;
;       CHECK IF 80287 IS PRESENT                             ;
;*************************************************************;
                PUBLIC  _NDP_PRESENT
_NDP_PRESENT    PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        INT     11H                     ; BIOS EQUIP CHECK
        TEST    AL,02H                  ; IS 80287 BIT SET?
        JZ      NO                      ; NO MEANS NO 80287
        MOV     AX,01h                  ; RETURN TRUE
        JMP     NDPEXIT                 ; ALL DONE
NO:     XOR     AX,AX                   ; SET AX TO FALSE
NDPEXIT:MOV     SP, BP                  ; RESTORE SP
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_NDP_PRESENT    ENDP
;*************************************************************;
;       _CPU_TYPE                                             ;
;       CHECK IF CPU IS 8088/8086, 80188/80186, 80286, 80386  ;
```

```
;*************************************************************;
                PUBLIC  _CPU_TYPE
_CPU_TYPE       PROC    NEAR
        PUSH    BP                      ; SAVE FRAME
        MOV     BP, SP                  ;
        PUSHF                           ;
        XOR     AX,AX                   ; ZERO AX
        PUSH    AX                      ;
        POPF                            ; TRY TO PUT 0 INTO FLAGS
        PUSHF                           ;
        POP     AX                      ; SEE WHAT WENT IN FLAGS
        AND     AX,0F000H               ; MASK OFF HIGH FLAG BITS
        CMP     AX,0F000H               ; WAS HIGH NIBBLE ONES
        JE      _8X                     ; IS 8086 OR 8088
        PUSH    SP                      ; SEE IF SP IS UPDATED
        POP     BX                      ; BEFORE OR AFTER IT IS
        CMP     BX,SP                   ; PUSHED
        JNE     _18X
        MOV     AX,0F000H               ; TRY TO SET HIGH BITS
        PUSH    AX                      ;
        POPF                            ; IN THE FLAGS
        PUSHF                           ;
        POP     AX                      ; LOOK AT ACTUAL FLAGS
        AND     AX,0F000H               ; ANY HIGH BITS SET?
        JE      _286                    ; IS 80286
_386:   MOV     AX,03                   ; IS AN 80386
        JMP     CTEXIT                  ;
_286:   MOV     AX,02                   ; IS AN 80286
        JMP     CTEXIT                  ;
_18X:   MOV     AX,01                   ; IS AN 80188/80186
        JMP     CTEXIT                  ;
_8X:    MOV     AX,00                   ; IS AN 8088/8086
CTEXIT: POPF                            ; RESTORE ORIGINAL FLAGS
        MOV     SP, BP                  ; RESTORE SP
        POP     BP                      ; RESTORE BP
        RET                             ; RETURN
_CPU_TYPE       ENDP
_TEXT           ENDS
                END
```


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- Optional Assembly Language Listing Intermixed with MCC68K C Source Line Number
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The Microtec MCC68K C Cross Compiler is a complete implementation of the 'C' programming language as defined in The C Programming Language by Kernighan and Ritchie with extensions.

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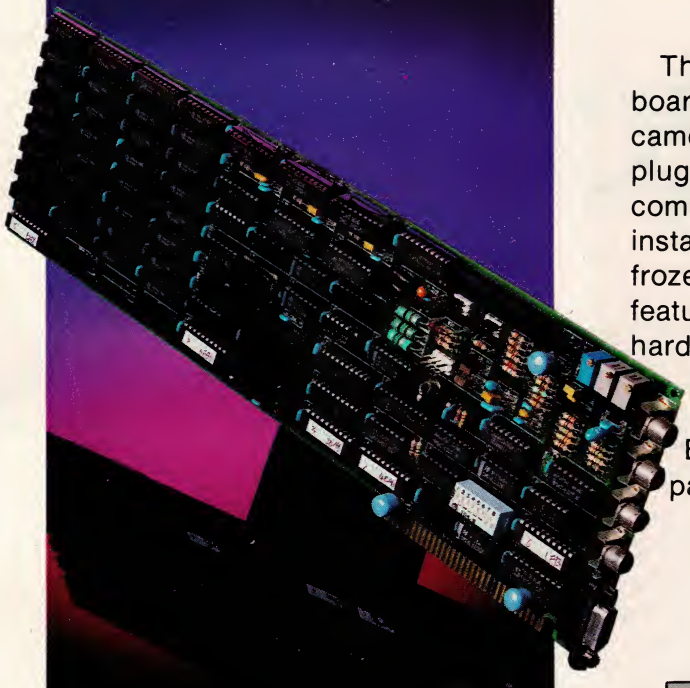

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Multilevel Debugger

Window-oriented CodeView heralds a new generation of products with full debugging capabilities at both the source code and assembly levels.

MARK S. ACKERMAN

Traditionally, PC software developers have not had many choices for debugging their high-level language programs. Most debuggers work in assembly language code; the programmer must be familiar with intricate details of how the compiler generates code in order to debug programs successfully. Commands are given to the debugger through a command line using cryptic incantations. In an age of mice, pull-down menus, and windows, most debuggers are throwbacks to the days of DOS 1.0.

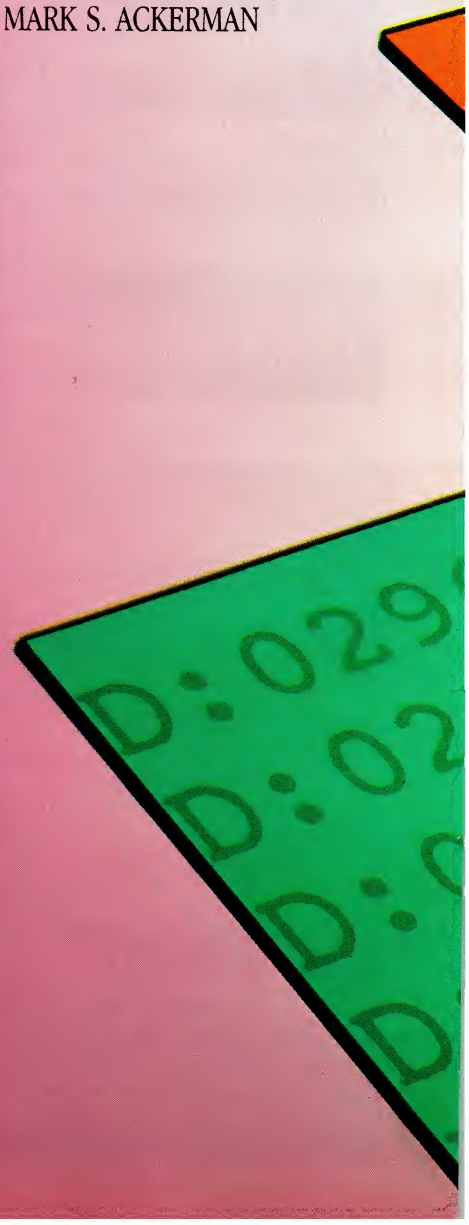
CodeView is Microsoft Corporation's attempt to advance the state of the art in debuggers. CodeView provides debugging at both the source and assembly language levels. For users who are familiar with assembly-level assistance, CodeView is compatible with both Microsoft's DEBUG and SYMDEB line-oriented debuggers. For high-level language programmers, CodeView allows almost complete debugging at the source-code level.

Assembly-level debuggers such as DEBUG always work at the level of machine instructions (either hexadecimal or assembly language mnemonics) and memory locations. Although appropriate for programs written in assembly language, DEBUG is not well suited to higher-level languages. The original structure of the program is obscured by compilation; at best, the compiler may produce a listing that shows the assembly language code generated from the source. In this case, the programmer must understand not only the source-level program but also the resulting assembly language code that is produced by the compiler.

SYMDEB, currently provided by Microsoft with its Macro Assembler version 4.0, extends the capabilities of DEBUG by adding limited support for debugging at the source-code level. The programmer can step through one source-code line at a time. Symbols for function names and global data can be used instead of absolute memory addresses. However, the debugger does not know the size or type of data designated by the symbol; the programmer must provide that information.

CodeView also allows debugging at the source-code level, but instead of examining bytes or words in memory, the programmer can examine variables as their program-defined types: integers, floats, strings, and structure members. Instead of stopping on an assembly language instruction, the programmer can stop on source lines. Both global and local variables may be examined, CodeView knows the size and structure of variables in the program.

Often, an assembly-level debugger is not necessary for application programming. Even for systems programming done in C, source-level debugging



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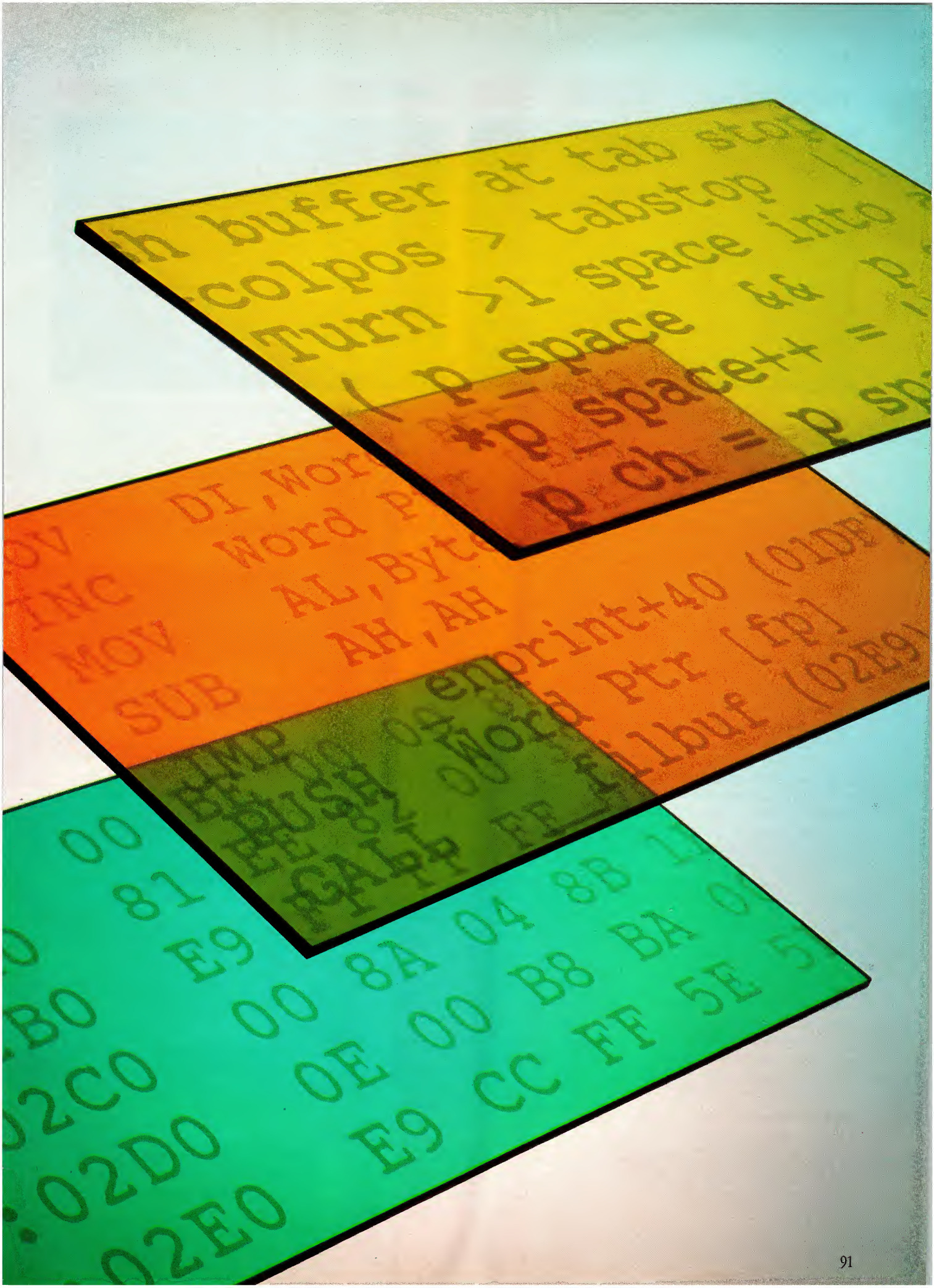
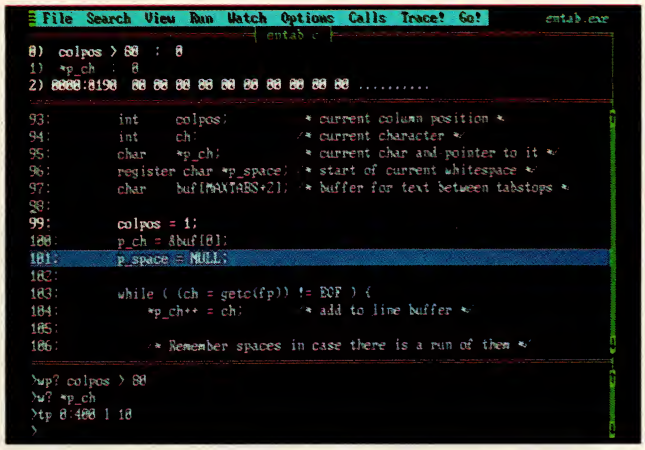
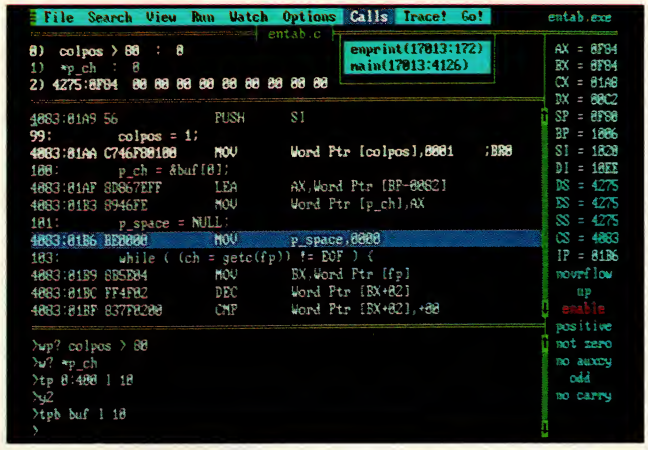


PHOTO 1: *CodeView Screen Layout*



The major components of the CodeView screen in window mode are, from top to bottom, the menu bar, the watch window, the display window, and the dialog window.

PHOTO 2: *Mixed Source/Assembly Listing*



For more detailed debugging, a mixed source and assembly listing may be used instead of straight source code. The watch window displays the active trace and watchpoints.

is possible. CodeView hides the assembly language details in most cases.

The CodeView debugger is distributed as part of Microsoft's C version 4.0 and FORTRAN version 4.0, and supports all memory models. It is not available separately. Microsoft C and FORTRAN are the only languages that currently support the extended debugging information required for CodeView. This review was done with CodeView and the Microsoft C compiler.

The Microsoft C compiler is fully compatible with the Kernighan and Ritchie standard. It provides five memory models and includes numerous library routines. It supports mixed language programming among other Microsoft language implementations and contains a built-in optimizer. (Version 3.0 of the Microsoft C compiler was reviewed in "The State of C," William J. Hunt, January 1986, p. 82.)

To use CodeView, a user adds two switches in the compiler invocation:

```
MSC filename.c /Zi /Od ;;;
```

where the **/Zi** switch has the compiler include additional symbol, line number, and debugging information for the linker, and the **/Od** switch turns off optimization. (Including optimization removes the correlation between source-code lines and object-code lines.)

After compiling, linking is invoked using the CodeView option:

```
LINK /CO filename ;;;
```

It is very important to use the version of LINK that is provided with the Microsoft C compiler, because previous versions do not comprehend the **/CO** (CodeView) option.

This link creates a .EXE file with the requisite debugging information. The .EXE file also executes without the debugger present. Because the default level of optimization is disabled by the **/Od** option, the resulting .EXE file may be larger and run more slowly than a nondebugging version of the file. The debugging information included in the .EXE file for CodeView's use also increases the size of the .EXE file.

The .EXE file header reveals to CodeView the presence of debugging information. This header is not present in .COM files, so the source-level debugging option is not available for them. However, .COM files can be debugged using assembly-level commands. Similarly, a .EXE file compiled or linked without the options that are shown above will lack information for source-level debugging; however, CodeView can still be used.

Unfortunately, CodeView cannot be used to debug Microsoft Windows programs. The version of SYMDEB that is provided with the Microsoft Windows Software Development Kit should be kept for this purpose. Considering the size of both CodeView and Windows, memory limitations probably would prohibit use of CodeView even if it were available. Approximately 200KB of memory was required to debug a 100-line program with CodeView.

LAYOUT OF THE SCREEN

CodeView can be used in either of two modes. The first is SYMDEB-compatible sequential interface. At a prompt, the user types in a command, and the output is shown on the lines that follow. This mode would normally be used only for a non-supported display or a non-IBM-compatible, MS-DOS computer. In the second mode, window mode, CodeView displays several windows of information at once. Photo 1 shows the layout of the CodeView screen in window mode. The top of the screen is reserved for the menu bar.

Below the menu bar is an area called the *watch window*, which displays the current values of selected variables or expressions. If no values are being watched (for example, whenever CodeView is started), this window is not present on the screen.

The *display window*, an area used for the source code, appears below the watch window (or menu bar if no watch window is present at the time). This area is also used for the assembly language code or another text file. Photo 2 shows the display window with the assembly code option selected.

At the bottom is the *dialog window*. Dialog commands, which are a superset of SYMDEB commands, are entered in this window, and CodeView's responses for some queries are given here. This area by default is small. CodeView retains a buffer of previous requests and responses in the dialog window through which the user can scroll. The sizes of the display and dialog windows can be changed easily.

To the right side of the screen is an optional vertical *register window*. Showing the registers and flags, it can be opened or closed with a keystroke. Assembly-level debugging, shown in photo 2, illustrates the layout of the register window. When debugging at source level, the register window is usually not needed.

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SEEING CODEVIEW

CodeView was tested on an AT with a Hercules Graphics Card, an AT with an IBM Enhanced Graphics Adapter (EGA), and an AT&T PC6300 with an AT&T adapter compatible with the IBM Color Graphics Adapter (CGA) and monochrome display. Both AT configurations were run under DOS 3.1, and the PC6300 with AT&T's MS-DOS 2.11.

On the ATs, CodeView recognized that DOS was being used and automatically entered the window mode when it was started. On the PC6300, the **/W** (window) and **/B** (black-and-white display) options had to be used to start CodeView in window mode.

Screen output is a difficult area for debuggers such as CodeView. When the program being debugged is not running, CodeView uses the entire screen to display debugging information. Whenever the program being debugged is started, a separate screen environment is provided for it. When the debugger resumes control (such as after a breakpoint), the program's screen is saved so that CodeView can reclaim the screen for debugging use.

If all of the application's screen output were done through the BIOS, CodeView could detect a BIOS video call (INT 10H) and restore the program's screen only when needed. In reality, many programs write directly to display adapter memory, avoiding the BIOS. CodeView could check every instruction for writes to display memory, but this would significantly slow program execution.

Instead, CodeView provides a good selection of compromises for handling screen output. On a monochrome adapter or an EGA/CGA program that changes display modes (for example, a graphics program), CodeView maintains a buffer of each screen in memory. Whenever the program is run, its screen is copied from the buffer into display memory. When CodeView takes control again, the screen is saved back into the buffer, and the CodeView screen is copied into display memory. This procedure causes the display to jump back and forth between the application and CodeView screen in a disconcerting manner.

With the CGA and EGA, CodeView uses two display pages in the video adapter memory: one for itself and the other for the program output. It flips between the two pages whenever the program is started, producing a much smoother transition between screens. The EGA also can be used in 43-line mode. The greater number of lines on the debugging screen in 43-line mode is helpful, but the annoying jumping between the CodeView screen and a 24-by-80 program screen becomes even more pronounced.

If a program is being debugged in a section of code where screen output is not being performed, the programmer can have CodeView disable the annoying screen-swapping that occurs during program execution. If it is carefully used, disabling screen-swapping can make CodeView much easier to work with. However, if the program does write directly to the screen, the output either overwrites part of CodeView's display or it disappears as CodeView updates its display.

The best option for debugging is one that is not mentioned in the Microsoft manual: using two displays. A CodeView command line switch, **/2**, places program output on the default display (selected by the DOS MODE command), and CodeView's output appears on the second display. Information about this feature is contained in the README.DOC file supplied on disk, rather than in the documentation.

Most commands can be executed by selecting from the pull-down menu bar, pressing function keys, or by typing the commands.

USING CODEVIEW

CodeView is started with the command:

CV options executablefile arguments

Options are provided to select window mode, sequential mode, black-and-white display, screen flipping and/or swapping, or IBM EGA 43-line mode. One useful option allows a sequence of commands to be executed when CodeView is started.

The name of the executable file to be debugged (including the .COM or .EXE extension) is given after any options. If the program expects any command-line arguments, they can be given after the executable file name.

Typically, the executable file is debugged in the same directory in which the source files reside. If CodeView cannot find the source files used to create the executable file, it prompts for the file's location. If a source file is not available, only assembly language debugging can be performed.

Every user should be able to find a comfortable interface with CodeView. Most commands can be executed by selecting from the pull-down menu bar, pressing function keys, or typing commands in the dialog window. Menu selections can be made with a Microsoft-compatible mouse or by using Alt-key combinations.

A mouse is used just as it is in Microsoft Windows. Items in the menu are selected by pointing to the main menu item, pressing a mouse button, and moving the selection bar to the desired item. Releasing the mouse button causes the selection to be made. The display and dialog windows have scroll bars that can be used to scroll through the source/assembly language listing or through previously entered dialog commands. The display/dialog separator line can be moved by the mouse to adjust the relative sizes of the two windows. The mouse also can be used to change any flag in the register window.

Microsoft has provided a new MOUSE.SYS driver with CodeView that can save and restore the mouse cursor, so that both CodeView and the program being debugged can use the mouse. Unfortunately, CodeView may cause problems for mice that do not use the Microsoft driver. Logitech Inc.'s latest Logimouse software has been made compatible. At the time of this review, however, Mouse Systems Corporation did not have PC Mouse software that worked with CodeView.

For keyboard use, the menu items have been named so that pressing the Alt key plus the first letter in the name will open the menu. Pressing the Alt key plus the first letter of the item in the opened menu will select that item. Commonly used commands are duplicated in the function keys, which allow actions such as set/clear breakpoints, single-step, and "run until this instruction is reached" to be performed with a single keystroke.

The familiar SYMDEB command-driven interface is available through the dialog window. The major changes and additions made to the SYMDEB commands are listed below:

- The **E** (enter) command, when typed with no arguments, executes the program in slow motion, highlighting each instruction as it is executed. If watchpoints and/or registers are being displayed, they are also updated.
- Commands have been added to manipulate tracepoints and watchpoints.

- The 7 command can be used to display detailed information about the 8087 or 80287 numeric coprocessor registers and internal state.
- In many of the commands that require values, a C-style expression often can be used. The expression can include program variables, register names, and constants.
- In keeping with the high-level debugging nature of CodeView, the default base for constants is 10. For hexadecimal constants, the C convention of preceding the number with **0x** should be used. Alternatively, the default base for constants can be changed to 16 with the **N** (numeric radix) command.
- The **W** (write) command of DEBUG and SYMDEB is not supported. DEBUG or SYMDEB must be used for modifying executable files or patching absolute disk addresses.
- The **S** (Search) command is not supported by CodeView.

EXECUTING CODE

Program execution begins with a function key, menu, or dialog command and stops whenever a breakpoint, watchpoint, or tracepoint is encountered. The user can specify that the execution be done in slow motion or that it stop on the current cursor line (a temporary breakpoint). The current line of code being executed is identified by reverse video highlighting.

The Trace command lets the user step through the program one or more lines at a time. It steps into C functions for which there is source code, if the display window contains C code. If CodeView is at the assembly level, the Trace command moves into any function or interrupt except a DOS interrupt 21. CodeView moves through a macro's expansion only at the assembly level, and the source line expansion is not available. After each step, all watch expressions are updated.

The Program Step command, does not enter C or assembly language procedures. While it is similar to the Trace command, it steps over the called procedure to the next source line in the current procedure.

Once entered, a procedure must be stepped through or a breakpoint must be set in the calling procedure. This can be done by making use of the Call Stack command.

If the program enters an endless loop or if a problem is encountered during execution, control can be regained through Ctrl-C or Ctrl-Break. If the program has reset these keys, CodeView can be stopped with the AT's SysReq key. CodeView does not abort; it gracefully returns control to the user.

At any point, the program can be restarted, which starts execution from the beginning of the program, as if the debugger has just been entered. Breakpoint and watch expression definitions still are retained.

Often while debugging, the user needs to know the calling sequence and parameters, as well as the relation among procedures, not just the procedures themselves. The calls menu or Stack Trace command shows the calling sequence to the present execution location. Photo 2 shows the CodeView screen with the calls menu pulled down. The menu is dynamic, showing the current function at the top and the calling procedures below. **Main()** is always the last function shown in the calls menu. The values of the parameters are also given in the menu.

Unlike the other menus, the calls menu cannot be used by entering the combination of Alt key and the first letter of the menu item. The user must move the selection bar up or down the menu and then press the Enter key. This moves the cursor to the source code at the calling point (or the calling instruction if called from assembly language). The calling parameter list can then be examined. If the uppermost menu item is selected, CodeView returns to the current position.

SEARCHING CODE

Examining code is a straightforward procedure in CodeView. The user is able to search through the code with the search menu or dialog commands or by using the cursor keys.

The view menu or the F3 key allows the user to move from C to assembly language and back. The assembly language code is mixed code; the C source is contained in the assembler, where possible, as comment lines. Photo 2 shows the mixed source/assembly format. The C source comments can be turned off completely to get straight assembly language without symbolic references. When source code is not available, the user sees only assembly language instructions in the standard Unassemble format from DEBUG. This is true for all .COM files.

The Search function lets the user find a variable, label, or expression in the code. After selecting the Find or Label menu item, a dialog box appears, and then the search string is specified by entering a regular expression.

Regular expressions are standard in the UNIX environment; they form a comprehensive but enigmatic search language. Regular expressions can include wild cards and special search characters. An example might be **^buffer**, which searches for the word *buffer* at the beginning of a line. In the simplest case, a normal text string can be entered. To look for the occurrences of the C library function **fopen()**, the user can type **fopen**. However, to look for **buffer[i]**, the user would need to know to enter **buffer\[i]**. Similarly, the * does not work quite the same way as at the DOS level. Regular expressions are very strong in their searching and matching capabilities, and their inclusion is quite useful. The CodeView manual includes an excellent appendix on regular expressions.

Two types of searching can be performed with CodeView. The first is a text search that uses a regular expression to find any string in the source file. Through menu selections, CodeView can perform a text search both forward and backward in the source file. With a dialog command, only forward searches are possible. Oddly, the search-backward menu selection does not allow a search string to be entered; it uses the string entered for the last forward-search command. Because searching wraps around to the top of the file (instead of giving a "not found" message), a search-forward command may find an occurrence at an earlier line in the file. This mirrors the behavior of searches in UNIX-style editors, but may take some users by surprise.

For example, a search for the string **strcpy** would find the first mention of *strcpy* in the source file starting from the cursor position, whether it is a function call, a comment, or a declaration. Subsequent searches will find later occurrences of *strcpy*, until the search wraps around to the first occurrence.

The second form of search is a label search, which finds the definition of a function or label. The name given for the label must be complete and cannot be a regular expression. If a label has been defined in C, CodeView finds that location, changing source files if necessary. If, however, the label is defined in assembly language or in executable code, then CodeView changes to assembly language to display the code. For example, a search for **strcpy** as a label would move to the location of the C library routine, and the debugger would change to assembly level.

Modifying code can be done only at the assembly level. The Assemble Dialog command assembles 8086-family mnemonics. Some programmers find

this command invaluable; they use it to jump to a patch area where they can enter temporary bug-fixing code. Instruction mnemonics for the 8087 and 80287, however, are not supported by the in-line assembler.

DATA EXAMINATION

CodeView provides programmers with a familiar environment in which to examine data using several methods. The first is the old DEBUG command for dumping memory. Entering dialog commands such as

```
D DS:0x1F0 230
```

produces a hexadecimal dump of that portion of memory. CodeView follows SYMDEB in having ASCII, integer, word, real, and several other types of dumps.

Virtually all of the familiar SYMDEB commands have been included in CodeView—for example, the Display Expression dialog command. (This facility is also available through the Evaluate menu item on the view menu.) The Display Expression command displays the value of a subset of C expressions. An expression includes constants, variables, most C operators, and some type casts (structure or union type casts are not allowed). For example, the following command

```
? global_var + 5
```

prints the value 15 in the dialog window if **global_var** is currently 10.

At a simple level, the Display Expression command operates as a calculator. It is also possible to determine the address of a variable using the **&** operator. In addition, the result can be formatted in a manner similar to the **printf** statement. For example, the dialog command, **? 100 , x** , asks for the value of 100 decimal in hexadecimal. The **x** asks that result be printed as a hexadecimal. All of the normal **printf** types are possible: decimal integer, hex, octal, float, exponential, string, character, and various longs. Most importantly, the value of a variable ccan be determined in C notation with the Display Expression command. The expression

```
? ptr —>member[index] , d
```

is perfectly valid. Individual address calculations are unnecessary.

Because the C assignment and increment operators are supported in expressions, display expression also can be used to modify data. This point is not well made in the manual. In fact, the manual does not refer to this useful feature in the chapter on modifying data. Although the **E** (enter) command of SYMDEB is also supported, the advantage of Display Expression for changing data is that the type and size of the data are known, whereas Enter requires the programmer to specify the type and size.

The command **? var1 = 5** sets **var1** to 5. In a similar manner,

```
? structB.var2 + +
```

increments the current value of **var2** in **structB**. Display Expression does not allow function calls to be executed. Because C strings are supported by library function calls, rather than directly in the language, the only way to modify a string is to use the Enter command:

```
E string_name "the rain"
```

This creates a small inconsistency in the way data are modified.

CodeView also has facilities for examining data through watch expressions. The ability to evaluate an expression or variable whenever a breakpoint or tracepoint is reached is available through the watch menu or a dialog command. This evaluation occurs automatically whenever CodeView is active.

Watch expressions are shown in the watch window directly below the menu bar, sharing the available screen space with the display window. Therefore, the more watch expressions that are used, the smaller the display window. Four or five watch expressions are a reasonable number for a 25-line screen; the EGA's 43-line mode is especially helpful when several watch expressions need to be displayed.

Limitations on the visibility of variable names in CodeView can make entering expressions somewhat awkward. Watch expressions for a procedure's local variable cannot be entered until the procedure is called. In fact, at least one line of code in the procedure must be executed before any watch expressions can be entered.

To know the value of a variable in a calling procedure, the user must prefix the variable name with the procedure name:

```
W? procedure_1.variable_A
```

If this is not done, CodeView does not know **variable_A**'s value within **procedure_1**, even in a procedure that is called by **procedure_1**. As a matter of convenience, CodeView should allow the user to set the locality for variables in the watch expression through the location of the cursor in the source. CodeView should also allow watch expressions to be set for functions that have not been reached, so that a watch expression could be set up before debugging actually starts.

BREAK, TRACE, AND WATCH

Three facilities are provided to stop execution of a program whenever user-defined conditions occur: breakpoints, tracepoints, and watchpoints. Breakpoints are also found in DEBUG and SYMDEB. CodeView allows the user to set breakpoints visually with the F9 key, a mouse button, or a dialog command. The source line is then highlighted on the screen (see photo 1).

As many as 20 breakpoints can be set simultaneously. They remain in force until they are canceled or until the programmer leaves the debugger. They are retained when the program is restarted. Breakpoints can be temporarily disabled and then reenabled.

When the program is about to execute a code statement that contains a breakpoint, CodeView stops, sets the display window to the appropriate point in the code, and updates any watch expressions. The user can then enter any CodeView commands. By appropriately placing breakpoints and watch expressions, users easily can gain snapshots of their programs.

An additional feature of breakpoints is that, through the dialog command, CodeView can stop at the *n*th iteration of a code line. The dialog command **BP .211 75** causes CodeView to stop when line 211 is executed for the 75th time. This is ideal for stopping near the end of a loop's execution. Through a dialog command, the user also can ask for the automatic execution of other commands when a breakpoint is triggered. For example,

```
BP .1034 "? i ; ? j = 4"
```

prints out the value of *i* and resets *j* to 4 every time the breakpoint is encountered in the program.

The second form of control is the tracepoint. It stops program execution whenever a memory location (or a range of memory up to 128 bytes) is modified. The expression defining the area of memory to be traced can be either a program variable name or a set of absolute memory addresses. Variables and memory ranges being traced appear in the watch window.

Watchpoints, the third and most powerful form of control, are expressions that are evaluated after every program instruction is executed. If the expression evaluates to any value except zero, the program is stopped. Watchpoints share the watch window with tracepoints and watch expressions.

Watch expressions display only the value of a variable, whereas watchpoints can cause the program to be stopped when their expressions are not zero. Watchpoints are shown in high-intensity text in the watch window to differentiate them from the similar-looking watch expressions. The combined total number of watchpoints, tracepoints, and watch expressions cannot exceed 10.

The cost of these features is reduced execution speed of the program being debugged. Breakpoints are relatively inexpensive unless they are contained in a loop with a very high pass count. Tracepoints and watchpoints slow the program down by a factor of approximately 1,000. Depending on the program, this may be significant. Programs that deal with external events (for example, serial ports, mice, or real-time clock interrupts) may not tolerate the delay. (CodeView can take advantage of debugging hardware that reduces the overhead of tracepoints and watchpoints. Atron's MiniProbe, an example of this kind of hardware, will be reviewed in an upcoming Product Watch.)

POWERFUL FUNCTIONS

Among CodeView's features are commands to set tabs, reset register values, copy CodeView output to both file and screen, and pause. The shell menu item allows the execution of DOS commands and a second COMMAND.COM.

One example of the power of the I/O redirection and pausing commands is the CodeView demonstration disk. The entire demonstration is orchestrated by using *script* files read in by CodeView. A script file is useful for quickly executing a program to the point where it was failing when it requires intermediate breakpoints and patches. All of the breakpoints and patches could be done in the script file.

CodeView's Load command loads ASCII files that contain no special formatting characters. This is useful for viewing C header files that have been included by the source program.

The on-line help screens are disappointing. Relatively little information is present; in general the screens serve as syntax reminders. For a complex product, CodeView offers very few screens.

CodeView's written documentation, with the exception of the Display Expression command, is good. The manual, which currently takes up one-half of one of the three Microsoft C manuals, includes sections on using the compiler and linker with CodeView, CodeView options, screen layout, and menus. In addition, each command has

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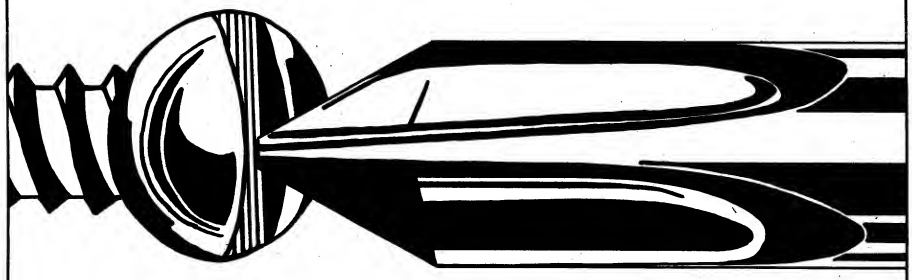

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"How to protect your software by letting people copy it."

By Dick Erett, President of Software Security

Inventor and entrepreneur, Dick Erett, explains his company's view on the protection of intellectual property.

"A crucial point that even sophisticated software development companies and the trade press seem to be missing or ignoring is this:

Software protection must be understood to be a distinctively different concept from that commonly referred to as copy protection.

Fundamentally, software protection involves devising a method that prevents unauthorized use of a program, without restricting a legitimate user from making any number of additional copies or preventing program operation via hard disk or LANs.

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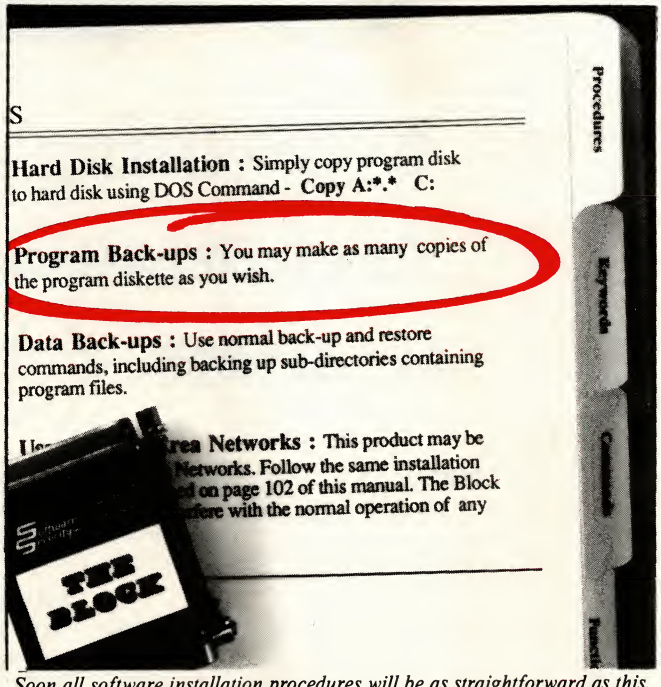

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We strongly believe that giving your software away is fine, if you make the decision to do so. However, if the public's sense of ethics is determining company policy, then you are no longer in control.

We have patented a device that protects your software while allowing unlimited archival copies and uninhibited use of hard disks and LANs. The name of this product is The BLOCK™.

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In reality, the only people who could object are those who would like the option of stealing your company's product.

"...eliminating the rationale for copy-busting..."

Since The BLOCK allows a user to make unlimited archival copies the rationale for copy-busting programs is eliminated.

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Each software developer devises their own procedure for accessing The BLOCK to confirm a legitimate user. If it is not present, then the program can take appropriate action.

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a short section with examples. An excellent, separate index is provided for the CodeView section in the manual.

The demonstration disk, "Learning Microsoft CodeView," provides a very good overview to the product and shows some of the ways that it can be used. The demonstration disk is currently available separately from Microsoft and can be freely copied and distributed. It is recommended.

Microsoft provides a technical support hotline at no extra cost, and telephone support for CodeView is good. Microsoft technical support people are able to answer questions quickly.

As a full-featured visual debugger, CodeView is professional and solid. It can handle source code and assembly language in all memory models furnished by Microsoft C. In addition, the interface for third-party debugging hardware can be used to enhance the performance of CodeView's watchpoints and tracepoints.

As with any product, CodeView can be improved. Documentation for the display expression and dual-display features should be clarified. A method for presetting watch expressions before a procedure is reached would be a welcome addition. Compatibility with memory-resident programs should be added. CodeView is not friendly to pop-up programs such as Borland's SideKick. During testing, calling SideKick from within CodeView caused the AT to freeze up, requiring a reboot.

Features such as the execute mode and watch expressions provide quite a powerful method for monitoring a program's behavior in detail at the source code or assembly level. CodeView's features for source-level debugging make it much less intimidating to the programmer who is not familiar with assembly language or machine instructions. While providing debugging at source level, CodeView has not sacrificed the ability to perform the more traditional low-level debugging.

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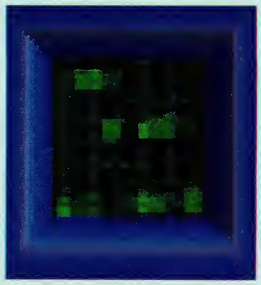

Mapping PC Address Space

AUGIE HANSEN

Memory and I/O address maps can help developers identify the available memory and port locations for application programs.

The Intel 8086 family of microprocessors, including the 8088 and 80286 chips that are the backbones of the IBM PC product lines, cannot operate in a vacuum. They must communicate with entities outside themselves to perform useful work: memory, both RAM and ROM; and external devices such as display systems, disk drives, and keyboards.

The microprocessor accesses memory and external devices in two primary ways. It uses a set of address leads to form either memory addresses or I/O addresses (called ports). The 8086/88-based machines have 20 address leads, permitting direct addressing of up to 1MB of memory. Figure 1 shows the basic 20-bit address bus used by the PC, PC/XT, and PC*jr*. Machines based on the 80286 use an additional 4 address leads for a total of 24, yielding a maximum directly addressable memory of 16MB.

All of the 8086 family microprocessors are also capable of addressing up to 64K ports. This separate address space is accessed via some of the same address leads used to access primary memory, but the processor operates in a different mode when reading and writing ports. The microprocessor can access either memory or a port, but not both at the same time. Instructions such as MOV use the address leads to access memory, but IN and OUT instructions cause the processor to access ports in the I/O address space. IBM chose to use only the first 10 address leads (A0-A9) when addressing ports, so PCs nominally have access to only 1,024 ports.

Certain areas of the memory and I/O spaces of a PC are reserved for system uses. The uses are, for the most part, common across the PC family, with some variations. One of the problems faced by developers is knowing which memory locations and ports are used by a given machine and which are available for use by application programs. The PC, PC/AT, XT, and PC*jr* (and most compatibles) can be treated identically for certain classes of system data and access points, but variations have been introduced that must be accounted for in program designs.

The memory and I/O address maps in this article are designed to aid programmers and hardware designers by making memory and port information readily available. The maps provide an overview of the allocation of memory and I/O address spaces in the PC machines. Areas of particular interest are expanded to show additional detail.

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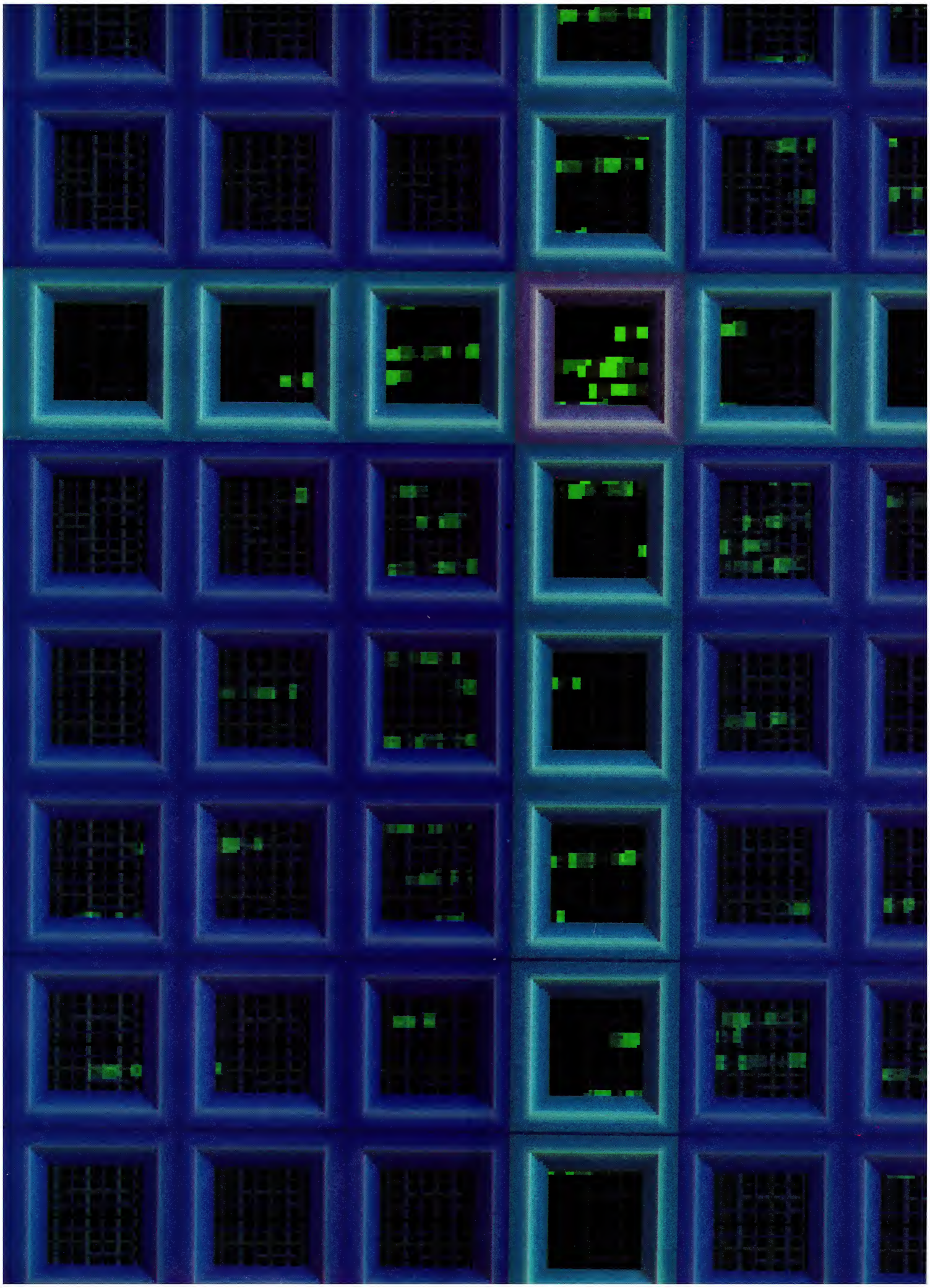


Only the first 640KB of the 1MB of address space can be populated with RAM; this is the maximum amount supported by current versions of DOS. The rest of the address space is dedicated to system-related items, such as ROM BIOS, BASIC, expansion ROM for add-in boards, and video display memory. In the user area of memory, system data and interrupt vectors, device drivers, and the operating system (which grow with each new release) occupy a significant amount of space. Add to that a generous amount of space for the omnipresent resident utilities and a user-friendly shell or task switcher, and it is a wonder that any room is left for application programs to load and run, even on machines that are equipped with the full complement of memory.

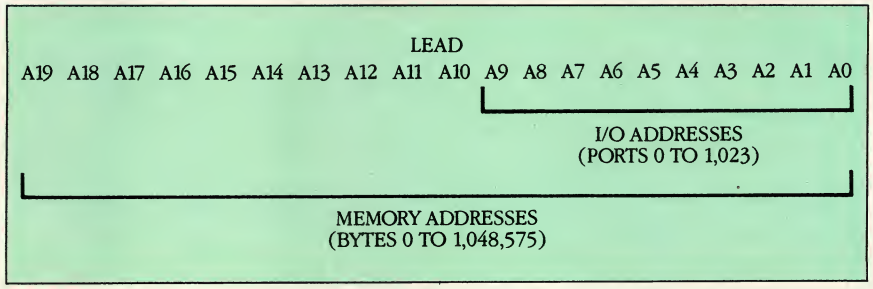
Figure 2 is a coarse memory address map showing the basic memory allocations envisioned by IBM. (All of the maps in this article use the convention of increasing addresses moving down the page and from left to right.) To run DOS, the primary RAM area must start at 0, be contiguous, and be large enough to run the operating system and its extensions (device drivers and other resident code) and to load and run the user's application program code and data. Isolated blocks of memory are not accessible to DOS except through special programs (RAM disk, print spooler, and so on), which are usually implemented as DOS device drivers or terminate-and-stay-resident (TSR) programs.

BASIC (except in the PC*jr*, which uses cartridge BASIC) and the ROM BIOS reside at the high end of the PC's memory space. The ROM BIOS is the firmware portion of the PC's basic input/output system, the low-level interface between the computer and devices that serve the user.

Versions of the ROM BIOS starting with the introduction of the XT use a feature called ROM SCAN to look for additional ROM (hard disk and other special BIOS modules) in the expansion ROM area. This enables an XT, for example, to boot from a hard disk instead of diskette drive A:. Any executable code found in the expansion ROM area is given control after the primary bootstrap sequence completes. Control eventually returns to the BIOS initialization routine, which either loads DOS (or another operating system) or defaults to BASIC.

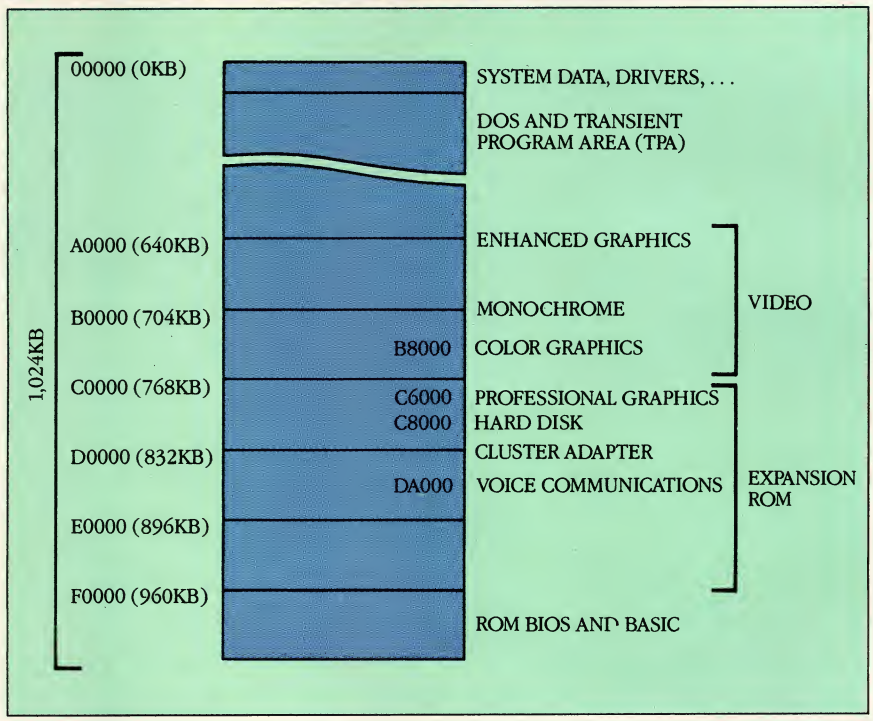
An area of special interest is the lowest portion of RAM. The low memory map presented in figure 3 shows the groupings of information in the re-

FIGURE 1: *PC Addressing*



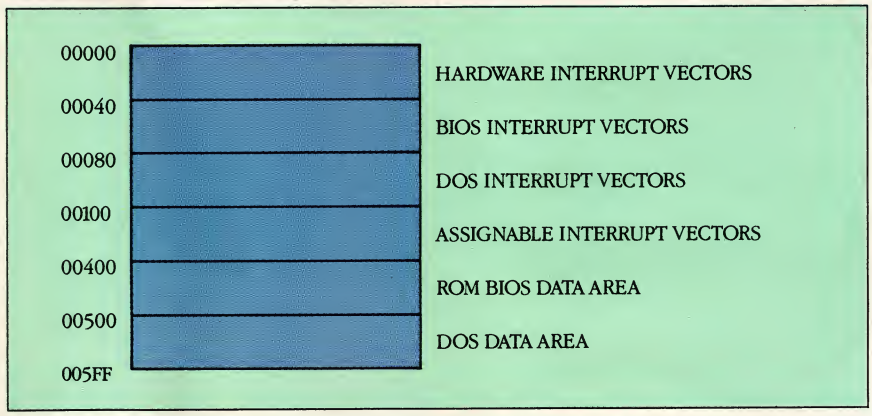
PCs based on the 8088 microprocessor use a 20-bit address bus. Machines based on the 80286 use a 24-bit address bus, yielding a 16MB address space.

FIGURE 2: *Coarse Memory Address Map*



Only the first 640KB of the PC's 1MB address space can be populated with RAM; the rest is dedicated to ROM, display buffers, and other system-related items.

FIGURE 3: *Low Memory Address Map*



Interrupt vectors point to the routines that provide wide range of services. Memory locations in the range of 400H to 5FFH hold ROM BIOS and DOS-related data.

gion from address 0H to 5FFH. The interrupt vectors point to the routines that provide a wide range of services on demand. Memory locations in the range of 400H to 5FFH hold ROM BIOS and DOS-related data. These locations are useful because they contain system configuration data, vital disk, keyboard, and video information, and miscellaneous status flags and values.

Some of the information, such as equipment flags, in the BIOS data area, shown in figure 4, is available with DOS and BIOS interrupts and should be obtained in that way to guarantee portability among PC models and versions of DOS. Other information, however, can be obtained only by reading locations directly. For example, two bytes provide keyboard status information. The first is at 417H. The value it holds is bit-significant to indicate the status of special keys, such as Caps Lock and Num Lock. The information can be obtained by calling BIOS interrupt 16H, function number 2 (Shift status). A second byte at 418H indicates whether one of the special keys is currently in a pressed or released state, plus some PC*jr*-specific key information. This information is not available through BIOS calls and must be read directly.

Reading information directly usually is not a recommended procedure. However, IBM says that it intends to maintain the structure and organization of the BIOS data area in its future PCs, so that programs can safely access the locations without becoming obsolete because of new equipment and operating system versions.

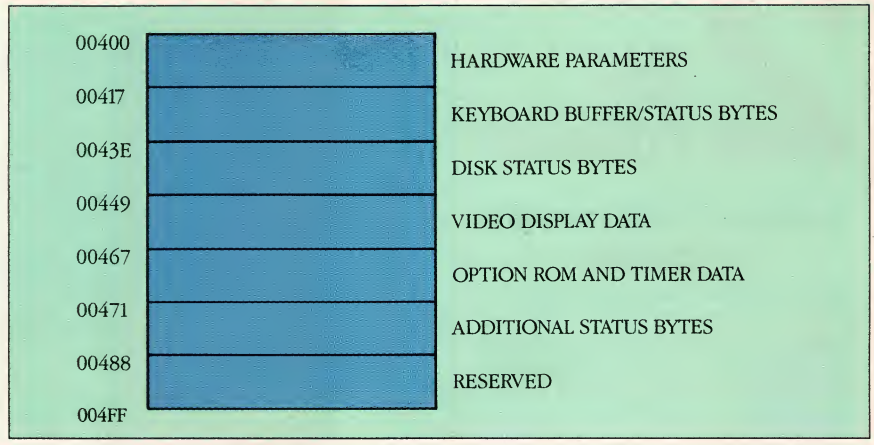
Above the transient program area (TPA) beginning at memory address A0000H is a reserved area for video adapters. Figure 5 shows the memory allocations for various video adapter configurations. Only a small sliver, 4KB in all, beginning at address B0000H is occupied by the standard IBM Monochrome Display and Graphics Adapter. The Color Graphics Adapter (CGA) starts at B8000H and extends upward for 16KB. Both a monochrome adapter and a CGA can be installed in a PC, but programs that depend on the standard video services provided by DOS and ROM BIOS can access only one display at a time. Programs that write to both display types simultaneously are using direct-screen access methods that are potentially troublesome to some PC operating environments (TopView, Windows, GEM). Quarterdeck's DesqView does not seem to be affected.

The region from A0000H to AFFFFH, although marked RESERVED by IBM, was used by some vendors as an extension of the TPA; DOS can be instructed to use RAM that is installed there provided it is contiguous with the lower regions of RAM. Several cards place an isolated block of memory in the region for use as a print spooler or RAM disk. These rogue memory allocations now conflict with applications that expect to find an Enhanced Graphics Adapter (EGA) starting at A0000H.

The EGA can contain up to 256KB of memory mapped into planes that can be allocated in several ways, (see "The EGA Standard", John T. Cockerham, October 1986, p. 48). When the EGA is masquerading as either a monochrome adapter or a CGA, its memory allocation starts at the expected monochrome adapter or CGA addresses and occupies 32KB. When configured to operate in pure EGA modes, the memory allocation starts at A0000H and occupies either 64KB or 128KB depending on the selected buffer address option.

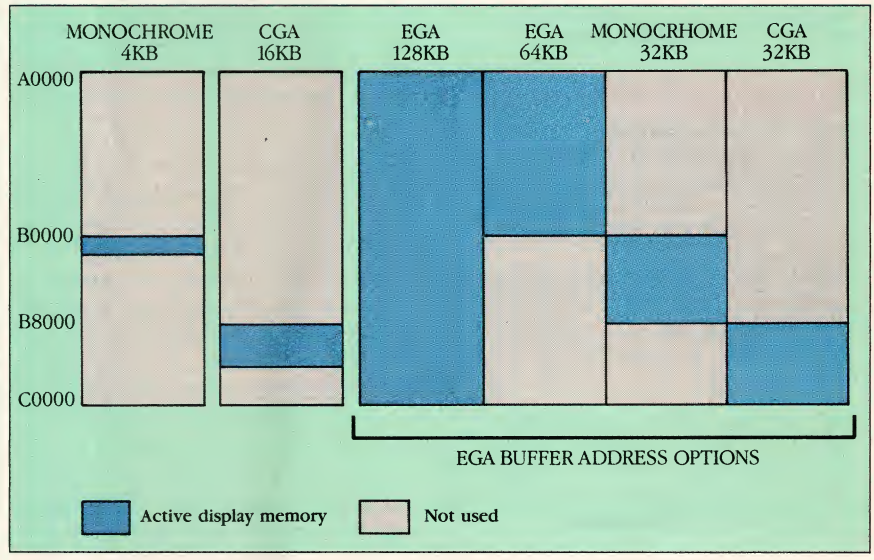
The maps specified by the overview in figure 6 show the I/O addresses that are currently allocated and reserved for future allocation by IBM. They are designed to help developers understand the mystery of the PC's I/O address space. Each row in a map (figures 7-12) represents 16 I/O addresses (ports), starting at the number shown at the left end of the row. Each figure maps 256 consecutive I/O addresses. The first 3 I/O address maps present information about the same block of ad-

FIGURE 4: *BIOS Data Area Memory Map*



Some of the information in the BIOS data area is available via DOS and BIOS interrupts and should be obtained in that way in order to guarantee portability.

FIGURE 5: *Display Memory Allocations*



The 128KB area beginning at memory address A0000H is reserved for video adapters. Only 4KB is occupied by the standard IBM monochrome display adapter.

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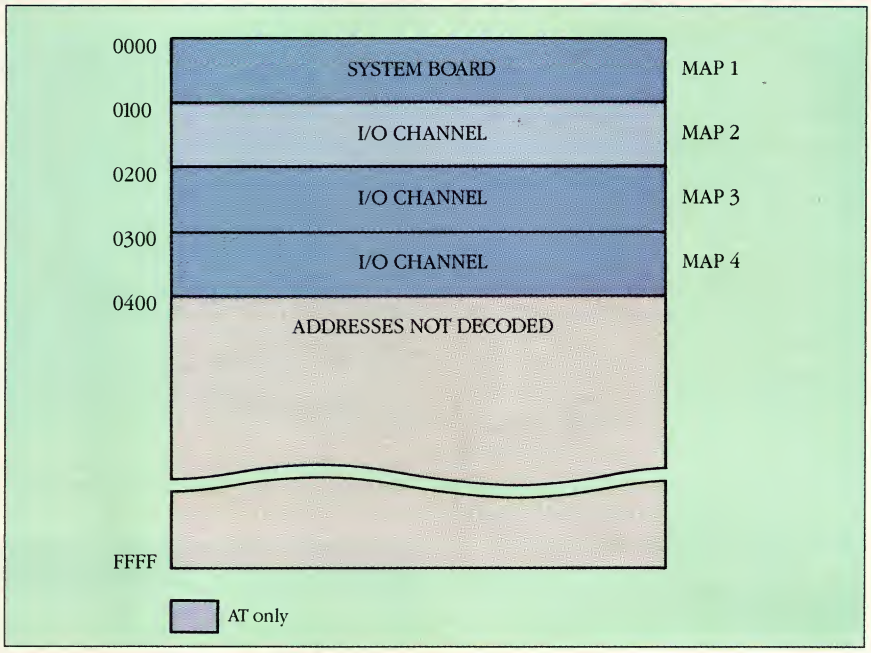
FIGURE 6: *PC I/O Address Space*



The I/O address space as defined by IBM is divided into several areas, with the first being reserved for system board devices and the remainder for I/O channel devices.

dresses for the PC and XT, the PC*jr*, and the AT because of significant differences in the allocations in each machine. The remaining I/O address maps are composites for the four major PC models.

For the PC, XT, and PC*jr*, when address lead A9 is low, addresses refer to I/O ports on the system board (000H-0FFH). Addresses in the 100H-1FFH range are not decoded. When A9 is high, addresses refer to ports in the I/O channel (200H-3FFH). The AT operates differently. It devotes the 000H-0FFH range to system board functions, as do the other models, but it allows the entire 100H-3FFH range to be used by adapters in the I/O channel. To date, the only allocation by IBM in the 100H-1FFH block of addresses is for the AT's hard-disk controller at 1F0H-1F8H.

Three separate maps are presented for the 000H-0FFH range. Figure 7 shows PC and XT allocations; figure 8 shows only PC*jr* allocations; and figure 9 shows only AT allocations. The AT claims nearly all of the I/O addresses, having both enlarged allocations for various support chips (timer, DMA, PIC) and added allocations for a second interrupt controller, a second DMA controller, the realtime clock, and the numeric coprocessor. CMCB at I/O address 0F0H is *Clear Math Coprocessor Busy* and RMC at 0F1H is *Reset Math Coprocessor*. A composite of the three maps reveals a potential problem for IBM; no free I/O ports are available in the block assigned to system board use. Future PC designs may need to expand the I/O address allocations and assign system uses to areas previously reserved for external devices in the I/O channel.

The 100H-1FFH range (figure 10) is used only in the AT and only for the hard disk. The map, therefore, shows many open I/O addresses in this range. Hardware that depends on the use of ports in this address range, however, functions properly only in an AT or a compatible machine. Consequently, for compatibility across the PC family, hardware designers should try to avoid this range of I/O addresses.

The 200H-2FFH address range (figure 11) appears to have a lot of open space, but it is actually a crowded range. Communications ports, special graphics interfaces, and hundreds of other optional hardware devices are all vying for very limited real estate in this area. A full 16 ports have been reserved for game I/O, although to date, systems use only port 201H. When an expansion unit is added to a PC, the 8 ports starting at 210H are used for communications between the units.

IBM is beginning to use the block of 48 RESERVED ports starting at port 220H. The voice communications adapter sits at port 21FH. (Three alternative assignments are above 3FFH.)

The block of I/O addresses starting at 278H is reserved for use by a parallel printer. If the system is equipped with a

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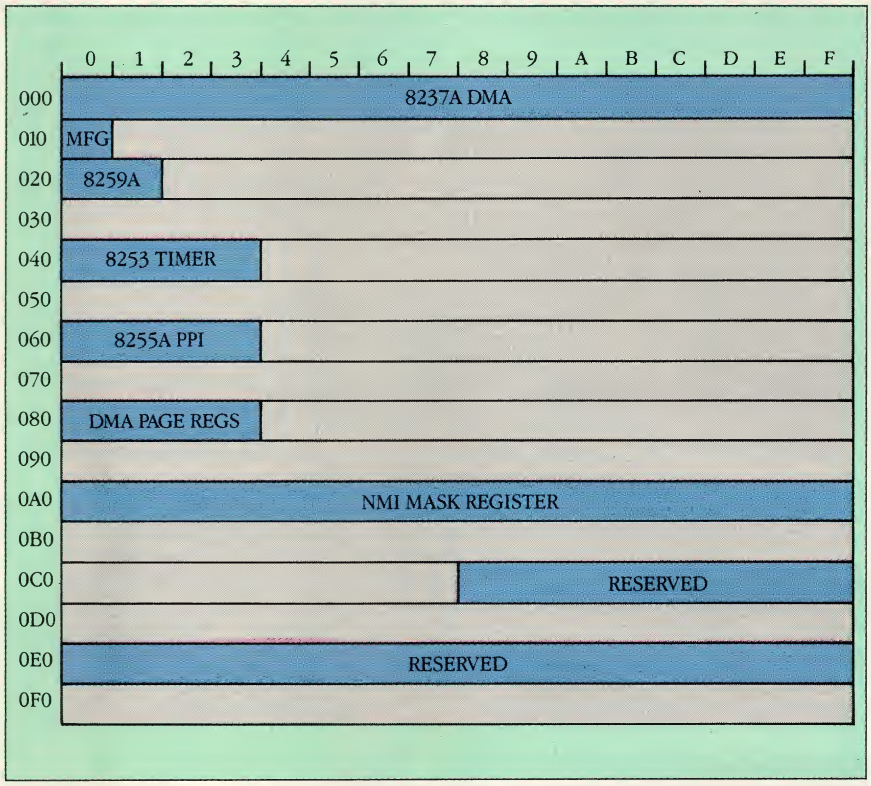
monochrome adapter, this becomes LPT3; otherwise, it is treated as LPT2. The initialization phase of the DOS loading procedure accommodates the hardware configuration automatically. The secondary asynchronous communications adapter (COM2) is allocated eight ports beginning at 2F8H. Additional allocations may be made for serial adapters at other I/O addresses; however, a specially written device driver or application code is required to access the new, nonstandard allocations.

The range of I/O addresses from 300H-3FFH (figure 12) also is mostly accounted for with the various allocations for network and communications adapters and the EGA that have been added in the last year or two. This range was already heavily laden with assignments for video display hardware (monochrome adapter and CGA), communications devices of both the synchronous and asynchronous persuasions, and the hard-disk controller (except for the AT hard-disk controller that was placed in ports 1F0H-1F8H). The parallel printer assignment starting at 378H is LPT2 if an IBM monochrome display/printer adapter is installed or LPT1 if not.

Neither IBM nor any other organization is making an effort to parcel out the available I/O addresses in a coordi-

FIGURE 7: *System Board Ports, PC and PC/XT*



PCs require I/O addresses only for the interrupt controller, timer, and speaker driver system devices located on the system board; quite a bit of open space exists in this map compared to that of the AT.

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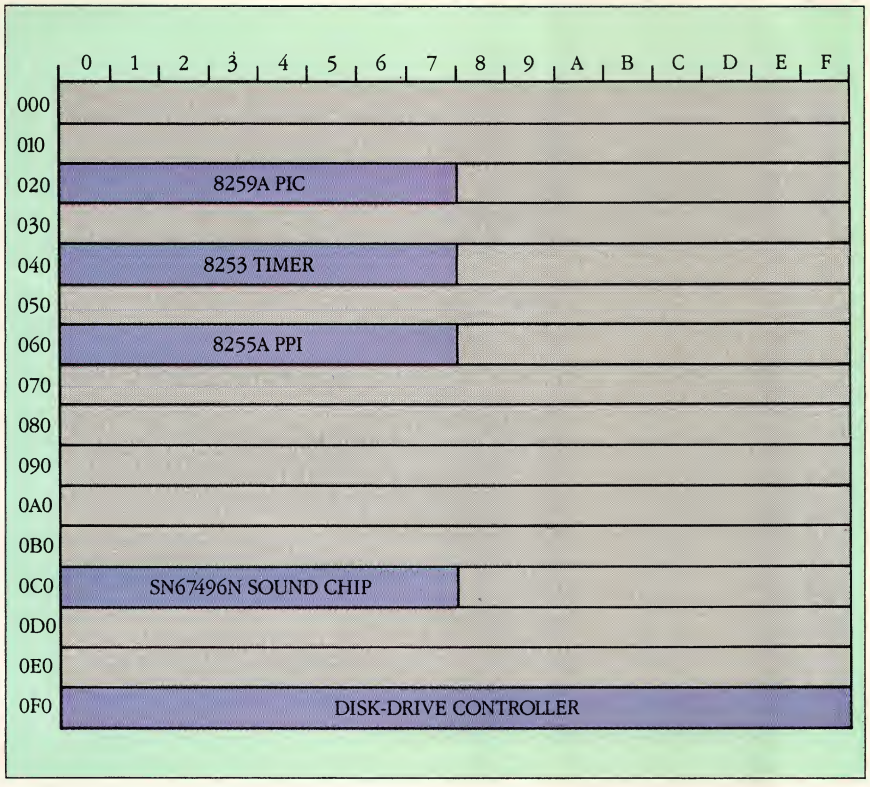
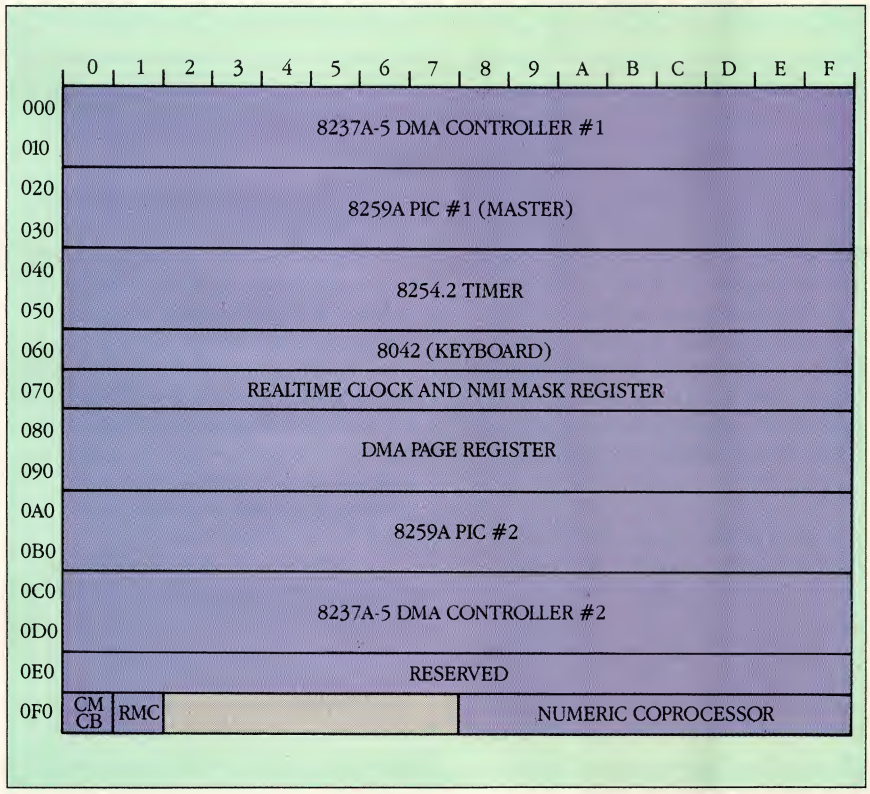
FIGURE 8: *System Board Ports, PCjr*



In addition to addresses for system board devices common to the PC, the PC*jr* requires addresses for both its diskette drive and its sound generator.

FIGURE 9: *System Board Ports, PC/AT*



The AT claims nearly all of the system board I/O addresses, having both enlarged allocations for existing support devices and designated locations for new ones.

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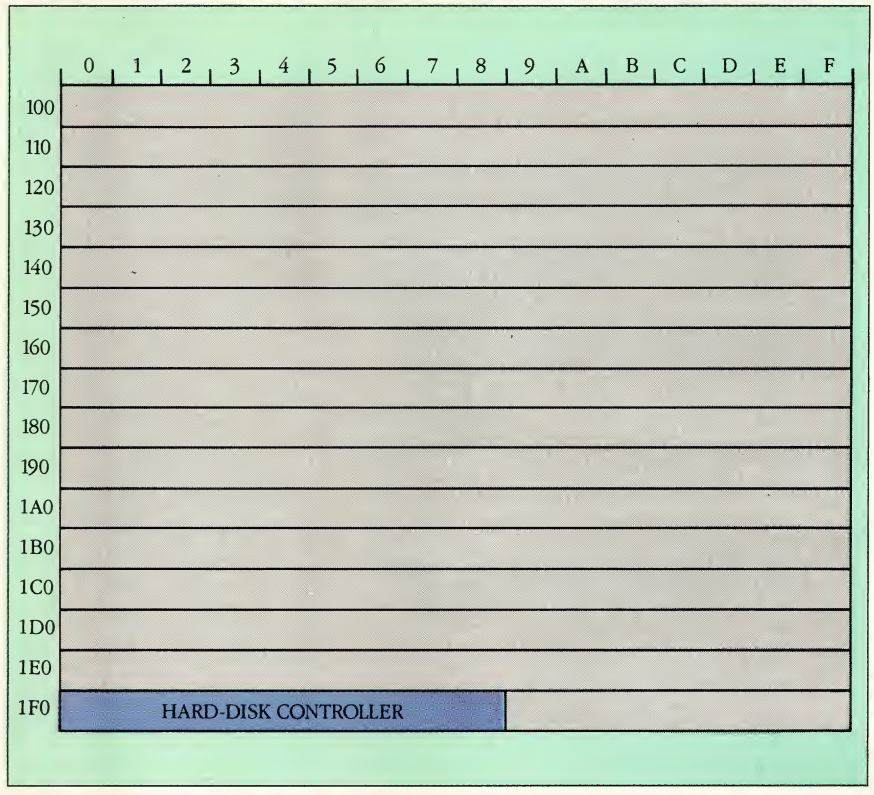
nated way. With the introduction of multiport serial boards (see "Beyond COM2," Augie Hansen, September 1986, p. 68), the crowding has worsened. Some of the multiport boards require 32 or even 64 contiguous I/O addresses, which makes it very difficult to find a home for them. This is why add-in boards that allow users a wide latitude in the selection of I/O addresses through switches or jumpers have definite advantages over comparable products that use fixed port assignments.

FIGURE 10: *I/O Channel Ports, PC/AT Only*



This range of I/O addresses is used only in the AT and only for the hard disk. Devices that depend on the use of these ports will not function properly on PCs.

EXPANDING THE SPACE

Adapter cards are free to do I/O address decoding using more than the ten lines decoded by the system board and by most of the earlier IBM adapters, thus permitting port numbers up to FFFFH if all 16 address lines are used. Recently introduced adapter cards are beginning to set the trend toward expanded I/O address space.

Expanded memory boards use two additional address lines to obtain larger allocations of I/O addresses (see "Expandable Memory," Ted Mirecki, February 1986, p. 66). IBM's Cluster Adapter can be set to decode addresses in the ranges of 790H-793H, 890H-893H, 1390H-1393H, or 2390H-2393H because it decodes two additional address leads. Some recent products, such as the serial boards made by ESE Technologies, use all 16 address lines to decode any of the 64K I/O addresses that can be presented on the address bus.

There is a catch, however. Any board in the I/O address space that decodes only the first 10 address lines will respond to any higher address, formed with a greater number of address lines, that happens to present the expected bit pattern on the lower 10 address lines. For this reason, developers still must be careful to avoid using previously claimed port numbers.

The advantage to using more address lines is that a given available port number, say 250H, can be multiplexed into as many as 64 separately addressable ports (one port specified by lines A0-A9 multiplied by the 64 patterns that can be specified by the upper 6 address lines). As more and more board manufacturers apply this technique, the port congestion problem will diminish a bit, at least in the near term.

ACCESSING MEMORY AND PORTS

The following examples show how to read and write memory and port values. Reading and writing PC memory would be easier if the Intel microprocessors had a linear address space. But because the registers that do the addressing are only 16-bits wide, a segment/offset scheme is used to address memory. Each address is specified as a segment, an address that falls on a paragraph boundary (a multiple of 16 bits), and an offset into that segment. Offsets range from 0H to FFFFH. Twenty-bit addresses are formed by shifting the segment value left by four bit positions (effectively multiplying it by 10H or 16 decimal) and adding the offset to the result.

The easiest way to examine PC memory is to load the DOS DEBUG program and use the dump command (**D**) to look at memory directly. Addresses are specified by using the segment:offset notation. For example,

```
-d 400:0
```

would show the values of a block of memory locations in the BIOS data area. (The minus sign is the prompt provided by DEBUG.) A subsequent **D** command without a specified address will bring up a display of the contents immediately following those displayed by the previous **D** command. This is a convenient mechanism for stepping through a range of addresses.

The DEBUG program also can be used to alter and write byte values anywhere in memory. The enter (**E**) and fill (**F**) commands can alter the values of a byte or a sequence of bytes. To initialize the range of bytes from 200H to 300H in the current data segment, for example, type

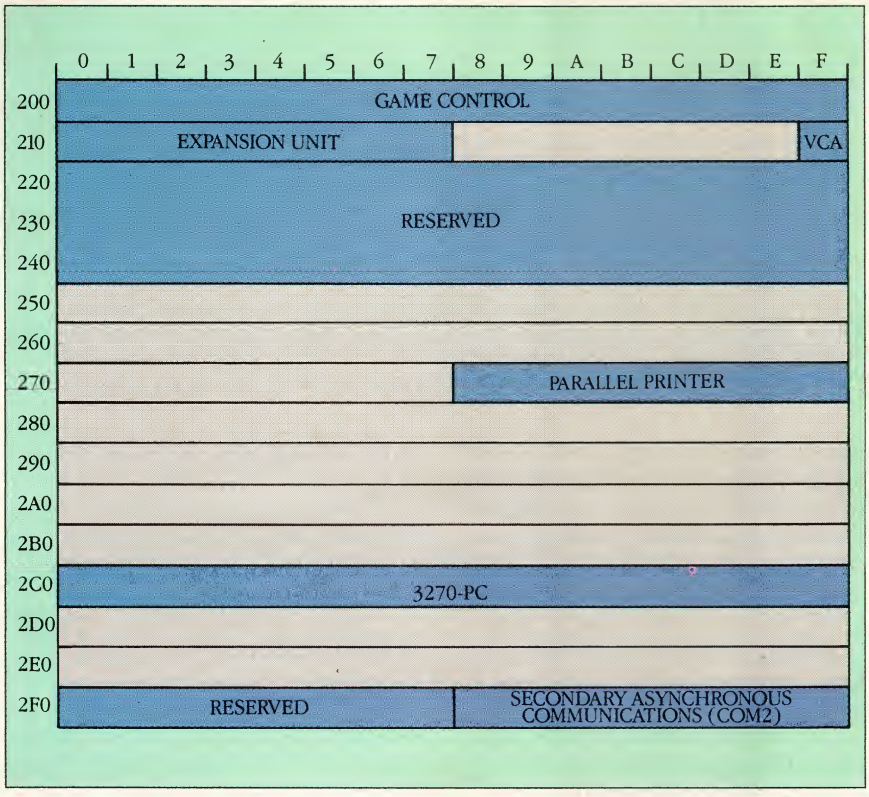
```
-f ds:200 300 0
```

and all bytes in the range assume the value of 0.

The interactive memory and port access offered by DEBUG is useful for examining the PC's inner workings and testing programs under varying conditions. Working with memory and ports from within programs is a different matter. Assembly language and nearly all high-level languages give programmers a variety of tools to read and write memory locations anywhere in the computer's address space.

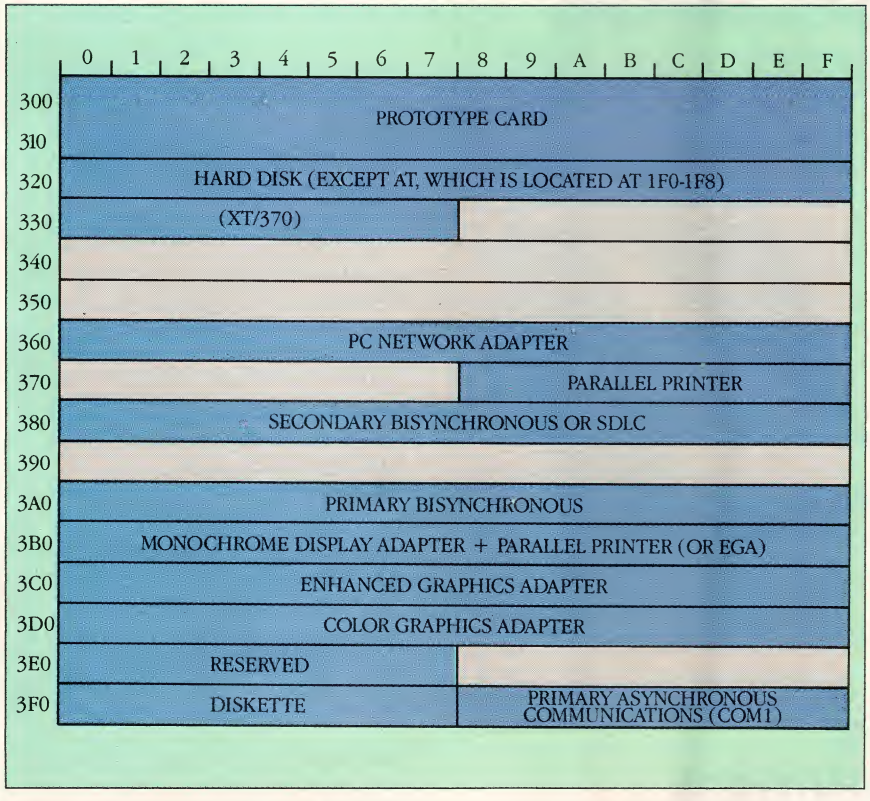
Assembly language provides the greatest level of machine access for programmers. An assembly language routine presented in "Instant Screens" (Augie Hansen, June 1986, p. 96) performs a synchronized, intersegment memory copy of data from a user-defined video buffer to physical display memory. The routine uses direct port access to handle critical timing tasks and a string move instruction to copy

FIGURE 11: *I/O Channel Ports, All PCs*



This range of I/O addresses is actually quite crowded. Hundreds of optional hardware devices, such as communications adapters, are all vying for ports here.

FIGURE 12: *I/O Channel Ports, All PCs*



This range of I/O addresses is also mostly accounted for by network and communications adapters and video adapters that have been added recently.

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FIGURE 13: *Assembly Language Port Access*

```
Listing 1.  SYNC.ASM
        .
        .
        .

;------ video status information ------
VSTAT   equ     3dah            ; video (CRT) status register
HRTRCE  equ     1               ; horizontal retrace bit mask

        .
        .
        .

        mov     dx,VSTAT                ; read c/g adapter status register
```

```
wait_horiz_refresh:
        in      al,dx
        test    al,HRTRCE               ; test horizontal retrace bit
        jnz     wait_horiz_refresh      ; loop until not in a retrace period
        cli                             ; can't tolerate an interrupt here

wait_horiz_retrace:
        in      al,dx
        test    al,HRTRCE               ; test horizontal retrace bit
        jz      wait_horiz_retrace      ; loop until retrace starts

        .
        .
        .
```

The CGA's control port can be examined to determine when the scanning beam is in horizontal refresh and retrace periods.

data quickly from the program data segment to the display data segment.

The essence of the routine is presented in the code fragment in figure 13, which shows how to examine the CGA's control port at 3DAH to determine when the scanning beam is in horizontal refresh and retrace periods. To avoid visual interference, CGA memory should be accessed only during horizontal or vertical retrace periods.

BASIC provides the PEEK function, which yields the byte value at the specified address (offset) in the current segment. A DEF SEG statement must be used before calling PEEK if the current segment is not the one where the byte of interest is located. The companion POKE statement allows programs to alter the contents of memory locations. It, too, requires the use of a DEF SEG to declare the correct segment for the location to be accessed. BASIC also has the INP function and OUT statement that permit direct access to ports.

C compiler vendors typically supply UNIX-compatible standard link libraries that are augmented with PC memory and port-access functions. Most C libraries provide a set of standardized memory functions, such as **memcpy** (copy memory), **memchr** (search for a character in a specified region of memory), and several others. In addition, the functions **inp** and **outp** are usually provided to permit direct port access.

Caution is advised when working in the PC's address spaces. Poking data into the wrong place, such as a hard-disk parameter table, could cause problems that are not easily reversed. The memory and port maps presented here are intended to be a general guide to where the important hardware elements of PCs are located and where new ones might be safely placed.

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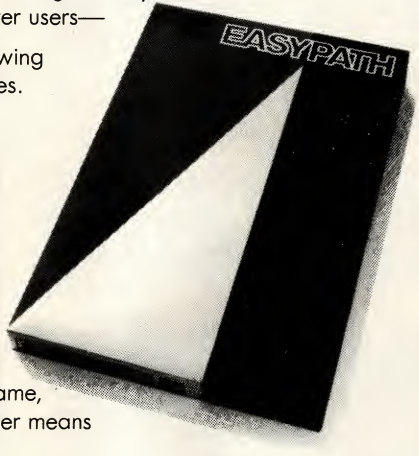

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REFERENCES

Davies, Russ. *COMPUTE!'s Mapping the IBM PC and PC*jr. New York: Compute! Publications, Inc., 1985. This book is already slightly dated because it does not cover the PC/AT, but it has many useful BASIC and assembly language examples.

Jourdain, Robert. *Programmer's Problem Solver for the IBM PC, XT & AT.* Englewood Cliffs, NJ: Brady Communications, 1986. This excellent book is a desk reference in addition to being a how-to book. It addresses many of the critical areas where programs meet machine and is full of helpful examples in several different programming languages.

Technical Reference manuals (Hardware Reference Library), IBM. A version of this document is available for each of the IBM Personal Computer models. The maps in this article are a composite of the information presented in the *Technical Reference* manuals.

Augie Hansen is the author of vi: The UNIX Screen Editor, *(Brady/Prentice Hall Press, 1986). His latest effort, an advanced C programming book called* Proficient C, *is due out in March from Microsoft Press.*

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JOHN T. COCKERHAM

To the field of computer languages, Niklaus Wirth has contributed three. His first, PL360, never really took hold as intended in the world of IBM 360 machines, yet within it Wirth had laid the groundwork for his next labor, the decidedly more successful Pascal. This second work continued a progression in design and technique that have culminated in a language that boasts strong typing and highly structured syntax, yet offers flexibility and low-level accessibility: Modula-2.

The language itself is reconsidered here (pursuant to its introduction in *PC Tech Journal* two years ago), and the current crop of Modula-2 compilers is appraised. (See "Modular Construction" and "Modular Implementation," Tom Woteki, Alan Frieden, Dov Levy, Thor Bestul, and Robert Stine, November 1984, p. 72 and December 1984, p. 154, respectively). The current list of language implementations includes Interface Technologies Corporation (ITC) M2SDS (and SDS-XP), Logitech, Inc. Modula-2, Modula Corporation PC Modula-2, PCollier Systems Modula-2PC, Pecan Software Systems Modula-2, and Workman & Associates FTL.

Wirth had introduced PL360 in 1968 as a single-pass, structured, high-level assembly language for use on IBM 360/370 mainframe machines. Some of the features of Pascal were evident in its forebear. An assignment statement had an ALGOL-like appearance—`r1 := r1 + 1;` meant add 1 to register 1, and FOR loops used the 360 registers as operands and compiled directly to hardware looping instructions.

With PL360, Wirth initiated segmentation as a device for breaking a large program's code and data into smaller blocks. Noteworthy was his use of 360 condition code (the 360 equivalent of flags on the 8088). Also, in PL360, the Boolean expression governing an IF statement could be a simple test on conditional code. For example,

```
IF < THEN...
```

tested the condition code, which was set as a side effect of a previous arithmetic operation for being less than.

However, the language lacked a comprehensive set of I/O facilities and did not interface particularly well to OS, IBM's mainframe operating system. PL360 never fully took hold in IBM 360 mainframe assembly language programming and remained something of an oddity in the computer world.

In 1971, Wirth released Pascal, a language that gained widespread acceptance as a didactic tool and as a development medium on the PC, but Pascal still lacked multiprogramming capabilities. When Wirth began designing Mod-

PHOTOGRAPH • STEPHEN LONGLEY

ula, it was with the specific intent to implement multiprogramming, multiprocessing, and separate compilation.

In PL360 and Pascal, a program's source code was compiled all at once (using include files as necessary). As Pascal programmers know, this can protract development. With Modula, Wirth introduced separately compiled entities called *modules*. Modula's syntax also eliminates some of the earlier (more clumsy) language constructs, such as

```
IF ... THEN
  BEGIN ... END
ELSE
  BEGIN ... END
```

This particular sequence was supplanted with the simpler

```
IF ... THEN ...
ELSE ...
END
```

Modula was implemented experimentally in 1975. In 1977, Wirth began designing an integrated programmer's workstation, the Lilith. In developing Lilith software, Wirth's goal was to devise one language that would serve both at high-level application and at low-level implementation for the operating environment. In fulfillment of this goal, Modula-2 was born.

A LANGUAGE APART

In spite of its impressive heritage, Modula-2 has not yet achieved widespread acceptance within the PC programming community, a fact that is probably attributable to the instability of some of the early Modula compilers. Certainly the language is structured to answer the requirements of complex programming.

A complete Modula-2 program consists of one or more separately compiled modules, each of which has two parts, the *definition* and the *implementation*. The two usually are specified in separate files. The definition module contains the declarations of identifiers to be made visible to other modules; it resembles the header file in C, broken into small pieces. The names and arguments of procedure calls, data structures, and enumerated constants typically are written into the definition module. All of the systems reviewed here compile definition modules into a more compact form to allow the compiler faster access to symbol definitions. The details of how a particular module performs its task are hidden in an implementation module—the actual executable code for the procedure named in the definition module.

To use an identifier belonging to a definition module, the *client* module (the module desiring such use) must import it. The IMPORT statement specifies to the compiler the name of the definition module in which the identifier to be imported is defined. The compiler searches for and incorporates any symbols named in the IMPORT statement into the compilation of the client module. This includes procedure headers, along with definitions of procedure parameters and their types.

The philosophy behind the formulation of this construction is very powerful. In following such a format, project designers can specify the interfaces between procedures first, by building definition modules that define types and procedure headers. Then, varying implementations of a particular procedure can be substituted without ever changing the original definition, and because the implementation details are hidden from the other modules, no other module will come to rely on the details of implementation.

During compilation, only those definitions of interest to the client, as specified in an IMPORT statement, are included (unlike C, which includes the entire global header file). To enforce this development style further, a Modula-2 system also must check the consistency of definitions across the definition

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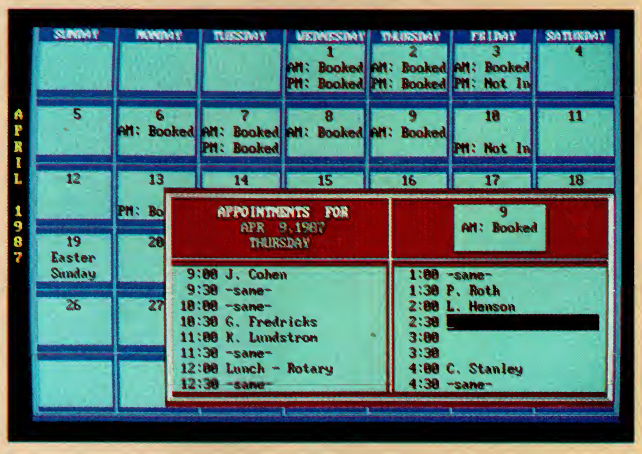

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Then Bob drew the appointments window, built an appointment file, filled in the connecting code and tested it — ONE HOUR AFTER HE STARTED!

Testing was a breeze. Screener doesn't just write code, it compiles your source, displays a screen, gets the changes, then replaces the old code in your program.

So here are Bob's appointment screens. You can see the source listing to the right. We marked all the code Screener wrote for him.

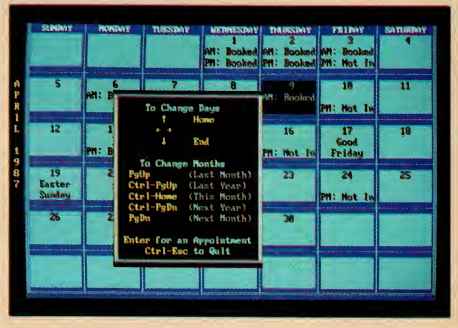

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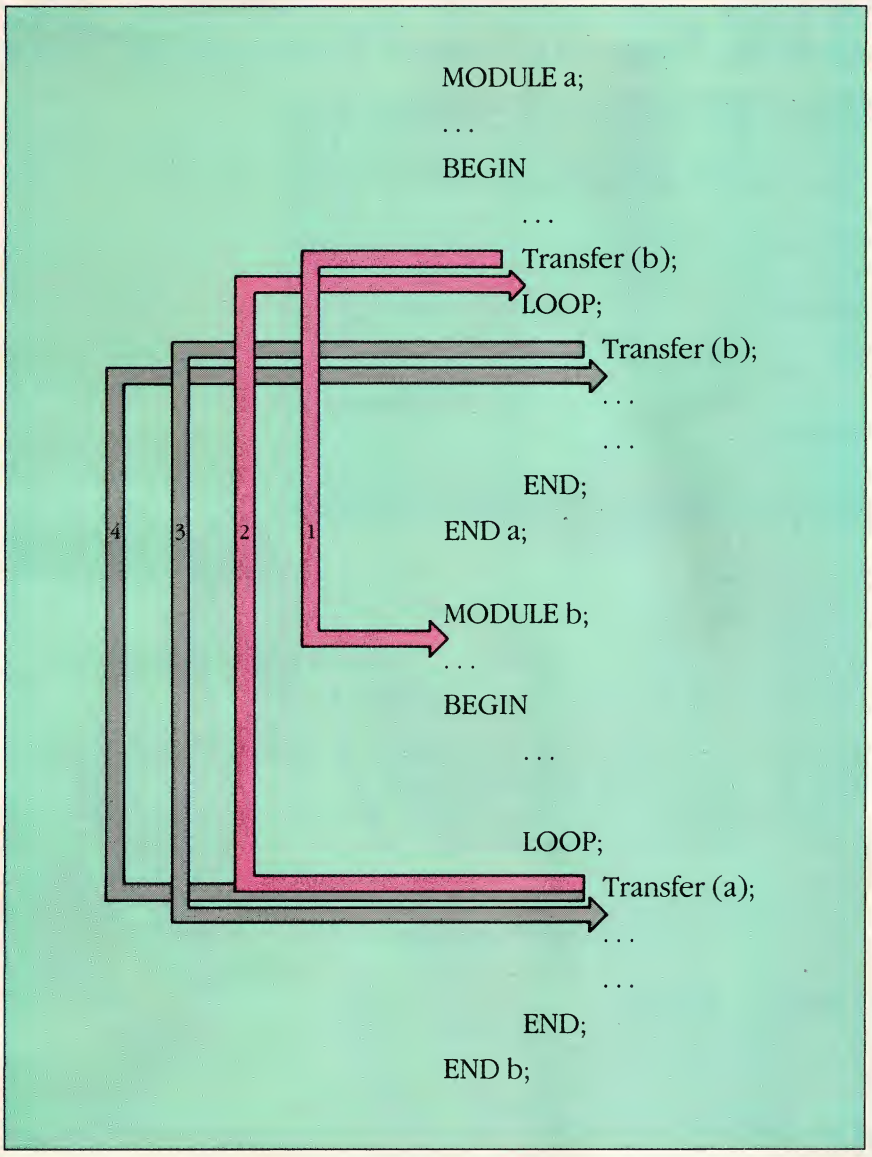
FIGURE 1: *Coroutine Execution*



Coroutines are procedures that share the same thread of execution. A Modula-2 module relinquishes control through a call to the procedure Transfer.

modules and implementation modules. This ensures that the definition module has not changed between the time that the implementation for a definition was compiled and the time the client module imports that definition.

Modula-2 demands strong typing of operands. The rules governing compatibility during assignment operations are strictly enforced, but may be defeated by explicit coercions, called *type transfers* (which are similar to casts in C and free union variant records in Pascal). Modula-2 library routines provide type conversions whereby the equivalent value is calculated. This differs from coercions in which the storage that is occupied by the identifier is reinterpreted in the coerced type.

Like C and Ada, Modula-2 has no built-in I/O constructs. In place of these, Wirth described a standard set of library modules containing procedures and functions (which in Modula return values) that perform basic I/O and floating-point arithmetic.

The language lacks a GOTO statement, a situation for which there are strong theoretical and practical reasons. It has been proved that any code sequence incorporating a GOTO can be implemented using structured logic (fully supported by Modula-2) with identical effect. Certainly, programs that contain GOTO statements are more difficult to debug and maintain. Eliminating GOTO also makes certain tasks easier on the compiler code generator.

Modula-2 permits absolute memory referencing in a standard, portable way; however, support for CPU register manipulation, address arithmetic, port I/O, and software interrupt invocation are handled differently by each of the Modula-2 implementations.

One of the language's more important capabilities is, of course, its support of multitasking and multiprocessing. However, the PC is a single CPU system; therefore, true multiprocessing, in which multiple threads execute simultaneously on separate CPUs operating in the same memory address space, cannot take place. As a result, Modula-2 processes on the PC are limited to quasi-concurrent serial execution.

Each of the systems reviewed here implements multitasking as a form of multiprocessing, and each offers two different sets of multitasking services. First, *coroutines* are procedures that share a single execution thread. This concept is presented graphically in figure 1. In that figure, MODULE **a** interrupts its flow of execution by performing a call to Transfer, to pass control of the CPU to MODULE **b**. MODULE **b** continues to execute until it calls Transfer, which returns the flow of control to the point in MODULE **a** at which execution was suspended by Transfer.

The second set of services—including a task creation mechanism and scheduling algorithm—delivers true multitasking. Most of these Modula-2 systems provide multitasking by placing a runtime system on top of DOS. The runtime system takes control of key hardware interrupts, including the timer tick interrupt 1CH, in order to set up a multitasking environment. Interprocess controls with appropriate waiting and posting mechanisms are provided. Other library routines associate a process with a particular hardware interrupt and also provide the appropriate interrupt dismissal services.

A program or implementation module that has a priority associated with its execution is called a *priority module* or *monitor*. The priority value is specified in square brackets after the name of the module in the implementation, as in the following example:

```
IMPLEMENTATION MODULE
  InterruptHandler [0]
```

The relative meaning of the priority number depends upon the Modula-2 implementation; in most cases, the lower the number, the higher the priority. When a procedure is called within a priority module, the current execution priority changes to the module's prior-

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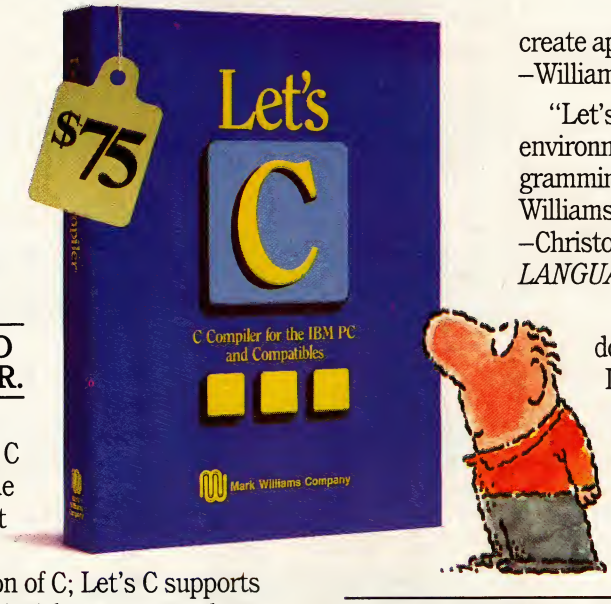

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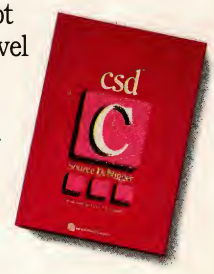

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ity. A lower priority procedure can call a higher priority procedure; however, a runtime error occurs if a high-priority procedure calls one of lower priority. When a procedure of a given priority is running, only a procedure of higher priority may interrupt and run. The procedure Listen provides a mechanism to temporarily lower a module's priority in order to allow other modules of a lower priority to execute.

Modula-2 is wanting in some areas. Despite its claims to be a low-level language, for example, it places the BITSET type between the programmer and the bits that comprise a word. Instead of logical operations, such as OR, AND, and XOR, BITSETs use set operations to create logical bit operations. BITSETs themselves are not difficult to understand, but they do place a semantic layer between the system programmer and the hardware. Another Modula-2 weakness is that its sets can contain no more than 16 members. Types defined as SET OF CHAR, so useful in Pascal text processing, are illegal in most implementations of Modula-2.

As with standard Pascal, Modula-2 makes no provision for defining variables with an initial value. Although PL360 had the capability of predefining global arrays with constant data, this feature was not carried forward into Pascal or Modula-2. (Note, however, that the typed constants of Borland's Turbo Pascal perform this service very well, and some Modula-2 vendors have indicated they may implement a similar feature in future releases, as an extension to the Modula-2 standard.)

The Modula-2 language definition is presently quite spare because most of Modula's I/O and mathematical functions reside in libraries. Wirth described a library of basic routines in his report of the Lilith implementation (*Programmming in Modula-2*, third edition, Springer-Verlag, 1985). These descriptions were not meant as standards, and, indeed, are not rigorous enough to be considered standard definitions. Unfortunately, this situation has led to the development of dialects that hinder code portability; however, the British Standards Institute is close to releasing a report that does include definitions of basic library routines.

SYSTEM COMPONENTS

Since Modula-2 and its implementations were last reviewed, three new contenders have entered this compiler field, from ITC, PCollier Systems, and Workman & Associates. Pecan Software absorbed Volition Systems' p-code Modula-2, and enhanced it with a native code generator similar to that included with UCSD Pascal. Apart from the Volition Systems' metamorphosis, the systems reviewed two years ago are still going strong: Logitech has greatly enhanced its compiler and Modula Corporation has altered its system to produce native code. Table 1 lists the individual compiler specifications.

TABLE 1: *Compiler Specifications*

	INTERFACE	LOGITECH	MODULA	PCOLLIER	PECAN	WORKMAN
VERSION	2.0a	2.05	1.1	1.0	1.0	1.1
PRICE	$80.88	$89.00	$195.00	$99.95	$79.95	$49.95
FILTER/ENVIRONMENT	E	F	F	E	E	F
RESOURCES						
Disk space	1MB	2MB	1MB	1MB	750KB	500KB
Environment (bytes)	40	80	40	15	0	15
Minimum memory to compile	256KB	320KB	256KB	256KB	128KB	256KB
COMPILER						
Type	4-pass	4-pass	1-pass	1-pass	—[a]	1-pass
Memory model	Large	Large	Large	Small	—[a]	Small
Complete language	●	●[b]	●[b]	●	●	●
SET OF CHAR	○	○	○	○	○	●
Long integer	●	○	●	●	○	●
Concurrency						
Monitors	○	●	●	●	○	○
Interrupts	●	●	●	●	●	●
Coroutines	●	●	●	●	●	●
Multitasking	○	●	●	○	●	●
Low-level						
In-line code	●	●	●	●	●	○
Register Access	●	●	●	○	○	●
Absolute Variables	○	●	○	●	●	●
Interrupts	●	●	●	●	●	●
Real numbers						
In-line native 8087	●	●	○	○	○	○
8087/80287 library	●	●	●	●	●	●
Detect at runtime	○	●	○	○	○	●
Compiler options						
Storage squeeze	○	●	○	○	○	○
Runtime checks off	●	●	●	●	●	○
Defeat case	○	○	○	●	●	○
Listing	○	●	○	●	●	●
Syntax extensions						
Predefined arrays	○	○	○	○	○	○
Multiple while	○	○	○	●	○	○
EDITOR						
Syntax directed	●	○	—[c]	○	○	○
Syntax checker	●	●	—[c]	○	○	●
Multiple files	●	●	—[c]	●	●	●
Windows	●	●	—[c]	●	○	●

● = *Yes* ○ = *No*
Part. = *partial*
Opt. = *optional feature, at extra cost*

Most of these products are complex program development environments, with debuggers, editors, and utilities. In comparing the packages, several factors must be considered:

- The compiler itself must be bug-free.
- It must accept valid Modula-2 source code and reject invalid lines, and it must produce correct code for the source lines it compiles.
- The degree of completeness of each compiler's implementation of the language must be measured, including priority and process implementation, absolute variables, in-line low-level code, and interrupt access.
- Any nonstandard, but convenient, extensions that the compiler adds to Modula-2 that ease the programmer's burden must be assessed.

	INTERFACE	LOGITECH	MODULA	PCOLLIER	PECAN	WORKMAN
LINKER						
Output file extension	.EXE	.LOD	.EXE/.RLX	.COM	.CODE	.COM
Foreign object import	●	○	●	●	●	○
Overlays	●	●	●	●	○	●
Link time (seconds)	27	34	37	6	—[a]	62
Exec. size (bytes)	28,948	36,352	75,360	66,560	—[a]	19,456
RUNTIME SERVICES						
Dynamic linking	○	○	●	●	●	○
DOS spawn/chain	●	●	○	○	○	●
Command line	●	●	●	●	○	●
Get environ. strings	●	●	●	●	○	●
DOS error level	○	○	○	●	○	○
LIBRARIES						
Terminal I/O	●	●	●	●	●	●
Graphics						
Mice	○	●	●	○	○	○
Display adapters	●	○	●	○	○	○
File I/O	●	●	●	●	●	●
Random file I/O	●	●	●	●	●	●
Math (8087)	●[d]	Opt.	●	●	●	○
DOS services	●	●	●	●	○	●
String-handling	●	●	●	●	●	●
Sound	●	●	○	○	○	○
Comm port	●	●	●	○	●	○
Decimals	○	●	○	○	●	○
Source code	●	Part.	○	○	Part.	○
DEBUGGING SERVICES						
Runtime	●	Opt.	●	○	○	●
Postmortem	○	Opt.	○	○	○	○
Stack trace	○	●	○	●	○	○
TOOLS AND OPTIONS						
Source code	●	Opt.	○	○	○	○
Customize	●	Opt.	○	○	○	○
ROM package	○	Opt.	○	○	○	○
Language import	○	Opt.	○	○	●	○
Make	●	Opt.	○	○	○	●
Cross-referencer	○	Opt.	○	○	○	○
Precedence	●	Opt.	○	○	○	●

[a]Pecan Modula-2 runs only in the Power System, these items could not be determined or do not apply.
[b]See text.
[c]Editor not provided.
[d]Present, but operated incorrectly.

All of these compilers implement the de facto Modula-2 standard defined by Niklaus Wirth in his report of the implementation on the Lilith; some offer extensions.

- The limitations of the compiler must be considered—how many symbols are permitted and how maximum code block length are evaluated.
- The compiler's generated code should be of a high quality.
- The memory model for the compiled code must be evaluated.
- The compiler's overall friendliness, including diagnostic messages and graceful recovery from syntax errors, is also an important factor.

After assessing the compiler, the steps necessary to generate a Modula-2 program are examined by evaluating the mechanism for linking the modules together into an executable program. These systems generate a variety of executable programs: some are standard .EXE files, others are specific to the Modula-2 implementation and require the particular system's loader to run.

Each vendor's implementation of Wirth's standard Modula-2 libraries also must be examined: InOut includes procedures similar to C's streams; Terminal implements low-level terminal access routines; Storage contains memory-management routines; and MathLib0 provides floating-point procedures, such as trigonometric functions. In his report, Wirth also mentioned windowing routines for both text and graphics, graphic pointing device services, and a menu system. Most of these packages provide the basic routines Wirth described; some even provide the windowing interface used on the Lilith.

The development tools are considered last. The debuggers, program editors, and cross-reference utilities are evaluated for their usefulness and user friendliness. Any additional tools, cross compilers or ROM packages, for example, round out the review.

Code quality. Quantifying the "goodness" of compiled code is difficult. Code generation itself is a mathematically undecidable problem; hence a more heuristic approach is needed. The compiler author, when writing code generators, faces a trade-off between code speed and code size in mapping processor instructions to language constructs. In the 8086 instruction set, many routes may be available to generate code corresponding to a particular Modula-2 language statement. Code generators that use the 8086 architecture to the fullest generate the best code.

To write a code generator that produces good code, the compiler author must thoroughly understand the target machine for which the code is being generated and choose the code model that best fits the machine. A code model encompasses the procedure activation record (the return address, parameters, and temporary variables of a procedure), standardization of calling sequences, static data allocation and data representations—the framework into which the compiled instructions are placed. The appropriate choices here will vastly improve the speed of finished product: the emitted code. (Note that *code model* should not be confused with *memory model*, a term that defines pointer size and the use of code and data segments in allocating memory to code and data at execution time.)

The Intel/Microsoft standard code model requires building the procedure activation record by pushing the parameters onto the stack (the ordering is not important because Modula-2 does not support procedures with a variable number of arguments), and executing a call instruction, which places the return address on the stack. Open array arguments (unbounded parameter arrays) include their lengths as part of the parameter. The activation record pointer (in BP) is then created by pushing the old value of BP (the caller's activation record pointer) onto the stack and

FIGURE 2: *Code Quality*

```
MODULA-2 SOURCE CODE --

VAR i,j,k: CARDINAL;

j := 0;   k := 10000;
REPEAT
    k := k - 1;     j := j + 1;     i := (k * 3) DIV (j * 5);
UNTIL k = 0 ;


CODE GENERATION --
```

INTERFACE	LOGITECH	MODULA	PCOLLIER	PECAN	WORKMAN
mov j,0	mov j,0	mov j,0	mov j,0	mov j,0	mov j,0
mov k,10000	mov k,10000	mov k,10000	mov k,10000	mov k,10000	mov k,10000
mov ax,k	mov ax,k	mov ax,k	mov bx,k	mov ax,k	mov ax,k
sub ax,1	dec ax	sub ax,1	dec bx	dec ax	dec ax
mov k,ax	mov k,ax	mov k,ax	nop	mov k,ax	mov k,ax
mov ax,j	mov cx,j	mov ax,j	mov k,bx	mov ax,j	mov ax,j
add ax,1	inc cx	add ax,1	mov bx,j	inc ax	inc ax
mov j,ax	mov j,cx	mov j,ax	inc bx	mov j,ax	mov j,ax
mov ax,k	mov ax,k	mov ax,k	nop	mov ax,k	mov ax,j
mov cx,3	mov bx,3	mov bx,3	mov j,bx	mov bx,3	mov dx,5
mul cx	mul bx	mul bx	mov bx,3	imul bx	imul dx
mov cx,j	mov dx,j	xchg bx,ax	mov ax,k	mov bx,ax	mov dx,ax
mov bx,ax	push ax	mov ax,j	mul bx	mov ax,j	push dx
mov ax,cx	mov ax,dx	mov cx,5	push ax	mov si,5	mov ax,k
mov cx,5	mov si,5	mul cx	mov bx,5	imul si	mov dx,3
mul cx	mul si	xchg cx,ax	mov ax,j	mov si,ax	imul dx
mov cx,ax	mov dx,ax	xchg bx,ax	mul bx	mov ax,bx	pop dx
mov ax,bx	pop ax	mov dx,0	nop	cwd	call divide
xor dx,dx	mov cx,dx	div cx	mov bx,ax	idiv si	mov i,ax
div cx	mov dx,0	mov i,ax	pop ax	mov i,ax	
mov i,ax	div cx		xor dx,dx		
	mov i,ax		div bx		
			nop		
			mov bx,ax		
			mov i,bx		

The compilers perform relatively naive code generation. Notable inefficiencies are FTL's call to a function to perform division and PCollier's insertion of NOPs.

copying the current stack pointer into BP. Parameters lie at positive offsets from BP. Temporary variables are allocated on the stack below BP (that is, at a negative offset from BP) by subtracting from SP the number of bytes of temporary storage space required. At the end of the procedure, the temporary variables are removed from the stack by replacing SP with BP, in effect moving SP up past the temporary variables to BP. A RET instruction with a stack decrement value removes the arguments from the stack and returns control to the caller.

Among these compilers, the method for passing parameters to procedures changes depending on the code model. The Logitech, ITC, and Workman & Associates compilers all pass their parameters on the stack. By contrast, PCollier's compiler passes its parameters by pushing them onto the stack and, during the call, copying its parameters into the data segment of the target procedure. This method may permit faster accesses to the parameters as compared to finding them on the stack because the processor does not have to calculate an effective address for each, but it requires code to move the parameters and also to preserve them and any local variables in the event that the procedure is called recursively. Modula Corporation's compiler pushes its parameters onto the stack before calling the target procedure, leaving stack clean-up to the calling routine.

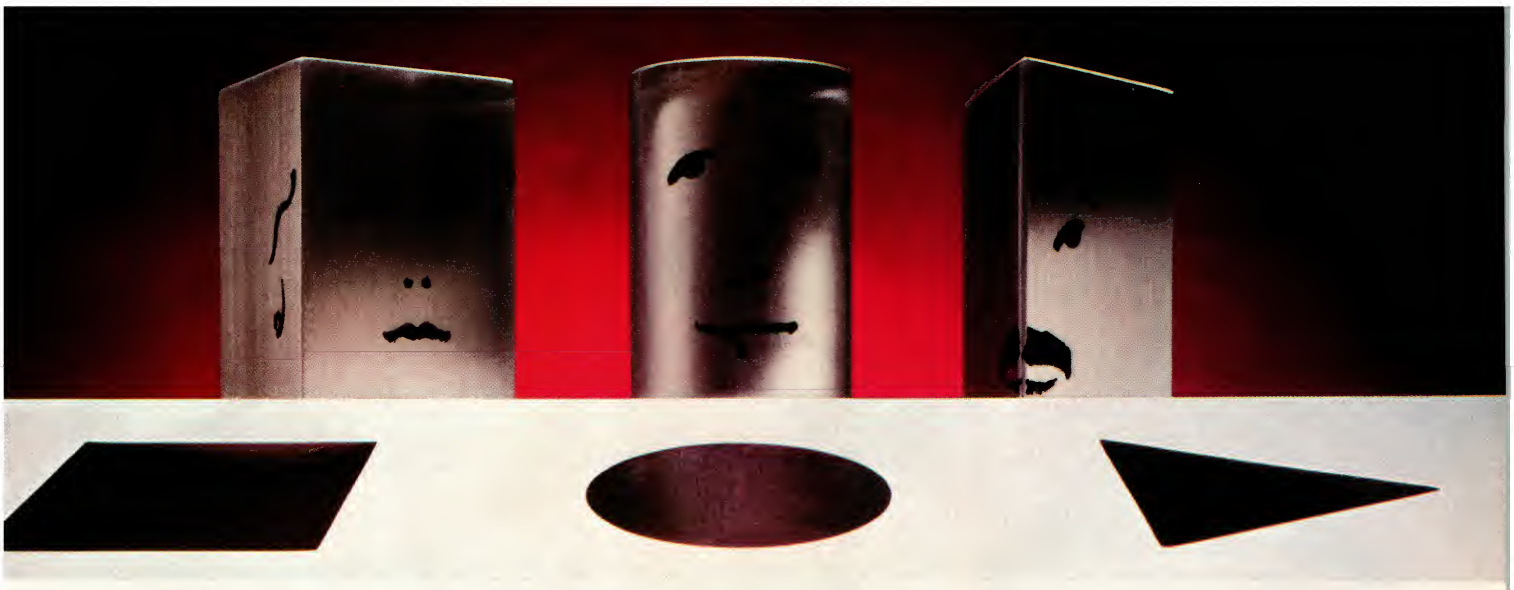
Apart from the choice of a method for calling procedures, other coding decisions must be made. The CASE statement, for example, can be compiled into several different sequences. Most compilers evaluate the case labels in the source code and watch for blocks of consecutive case labels. These blocks are then compiled into a jump table that points into the code generated for the CASE statement as a whole. The case label is translated into an index into the jump table. To cover nonsequential case labels, the code generated is typically a series of compares and jumps. Some compilers do not discriminate between consecutive and nonconsecutive case labels and simply generate a series of compares and jumps. Generating a jump table is possible during a one-pass compilation.

FOR loops also can be implemented in several different ways. The current Modula-2 definition specifies that FOR loops cannot have a variable step, and Wirth's Lilith report forbids changing the loop variable within the loop. This leaves the compiler author with several choices for generating the loop in machine code. For the most part, the compilers optimize on those loops with an increment of 1 by using the 8086's LOOP instruction. Upon entry into the loop, the compiler checks for degenerate cases (that is, it makes sure that the loop bounds are in the proper order and that the initial value for the loop index lies between them). Next, it calculates the number of times the loop must execute. The loop index and the loop count are then pushed onto the stack. The code of the loop is executed, and, at the bottom of the loop, the loop index and count are popped off of the stack and are updated. Then, the code branches to the top where the bounds are checked again, and so on, until the loop has executed the required number of times.

Very little optimization of code was observed among the reviewed compilers. In particular, the compilers were not sophisticated enough to "remember" that a useful register value had been loaded into a register for the use of a preceding statement. Instead, all necessary register values were reloaded each time a statement was translated to code, even when the proper values were present already.

Figure 2 provides a practical example of the differences in code generation. The figure shows a piece of Modula-2 source code and lists, side by side, disassembled listings of the cardinal code generated by each compiler (see table 2 for complete results from the performance benchmarks). Actually, the differences among the code samples generated were few: Modula Corporation's package performed the fastest because it did not use the stack for storing temporary variables; the FTL compiler pays a time penalty for calling a division subroutine; and PCollier's compiler has several NOP (no operation) instructions and insists on storing results through BX, as demonstrated by the last two instructions in its code sample.

The linkers. Each of the six compilers produces a proprietary object module format; therefore, each system must



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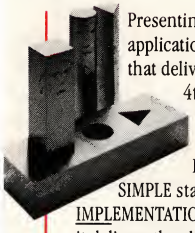

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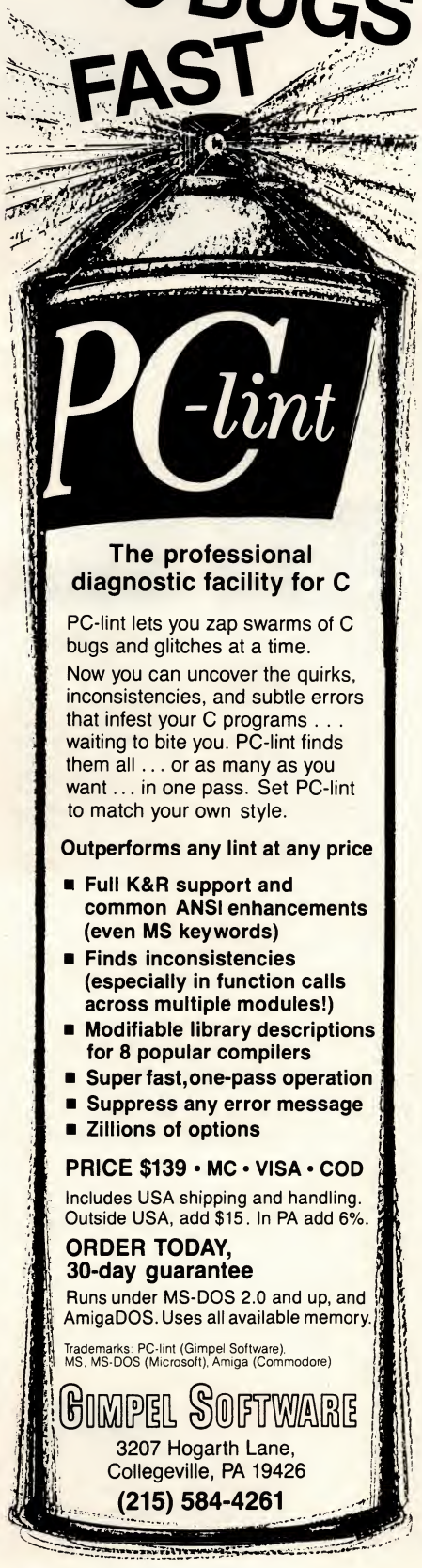

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TABLE 2: *Performance Benchmarks*

	INTERFACE	LOGITECH	MODULA	PCOLLIER	PECAN	WORKMAN
Object size (bytes)	3,196	4,092	5,830	6,760	—[a]	8,192
Compile time	26	58	45	42	160[b]	13
Repeat	53	49	49	88	45	46
For with step	47	41	59	106	57	52
Cardinal arithmetic	148	150	145	171	83	173
1-D array	154	167	264	326	261	145
2-D array	122	133	153	179	137	125
Empty call	107	112	175	928	545	68
Call with 4	182	178	446	1,065	604	153
Block move	217	216	300	304	145	213
Pointer chaining	269	200	2,056	498	130	143
8087/80287	20	18	—[c]	816	—[c]	—[d]
List build	456	4	7	8	—[e]	1
List dispose	460	600	30	5	—[e]	3
Eratosthenes Sieve	12	14	20	32	18	12
WriteString	140	126	146	166	253	224

All times are in seconds.
[a]Object size could not be determined; see text.
[b]These numbers are the result of dividing the actual times taken by 60. This compiler's Time function was undocumented—the resolution of the clock is in 60ths of a second.
[c]Compiler does not support the 8087/80287.
[d]A runtime bug occurred, preventing completion of the test.
[e]The runtime heap was too small to complete this test.

Much of the performance difference among compilers is related to the quality and tightness of the runtime support libraries and the efficiency of procedure calls.

provide its own linkers in order to produce an executable file. A linker is also desirable for other reasons. In a Modula-2 environment, the linker should be able to search for the component modules of a program as they are specified in the main module, without having to name them at the invocation of the linker. DOS LINK cannot do this.

Among these compilers, two approaches are used to link the executable file: *static* and *dynamic*. Static linking is the method in which a linker adjusts address references in a relocatable object module and optionally combines the module with other modules to produce a single executable code file. In dynamic linking, portions of the executable image can be retained on disk and loaded into memory as required and as memory becomes available. Dynamic linking is similar to having procedures linked as overlays except that overlay procedures are linked for a specific code segment offset. Routines loaded by a dynamic linker can be placed anywhere, and segment references are fixed only when the code is loaded. To understand dynamic linking, it is necessary to know how object modules are put together into executable programs that the operating system can run.

Static linking builds an executable code file. This file contains the executable machine instructions as well as relocation information for DOS; thus, instructions that use segment addresses can be adjusted to point to their absolute locations in memory. DOS fixes those instructions before starting execution. If the program implements overlays, the overlay manager calls DOS to load overlays as required, supplying DOS with the paragraph address for segment address fix within the overlay.

In dynamic linking (as used in Microsoft Windows), the executable image contains pointers to the names of routines that are to be linked when called at runtime. Routines to be dynamically linked are specified in the executable file. All static links are fixed as the executable file is processed by the linker. At runtime, the dynamic linking manager finds the requested routines and permits callers to call them. The fundamental difference in dynamic linking is that the routines are referenced by name, so that they can move around in memory from one call to the next.

Windows implements this feature as tables of *thunks*—snippets of code in a fixed location that always point to the entry of a routine, or to a fault manager that has the responsibility to reload the linked routine. The dynamic links are resolved at runtime.

Some of the implementations reviewed provide *dynamic loading* as a means of quickly checking out a pro-

gram during development. In dynamic loading, linkable object modules are loaded from disk at execution time, with all fixes occurring while the object modules are being loaded. Dynamic linking, by contrast, is done partly by the linker at link time, when intrasegment references are fixed. Intersegment references, however, are not fixed until execution time, because until that time, the runtime system does not know the location of any given segment.

In dynamic loading, a loader executes with the main module of the program. Procedure calls are intercepted by a runtime monitor that loads the appropriate module. As execution proceeds, modules that are called are loaded in turn. Dynamic loading is very handy during development, when a system requires a half hour to link statically. However, dynamic loading takes a toll on performance, as evidenced by the PCollier subroutine call benchmark. When producing a final product, the dynamic links need to be resolved to eliminate the performance penalty.

Most of the static linkers in these packages fix the instructions directly where the intermodule references are made. The Logitech and ITC compilers generate a FAR instruction, either a CALL or a JMP, leaving four bytes in the instruction's fields for the destination address to be filled in by the linker. Workman's FTL uses the small memory model, so only NEAR references are used, requiring only two bytes of space for the fix. Modula Corporation resolves references to a table of addresses at the beginning of each code segment, so indirect CALL and JMP instructions are made through this table.

PCollier's static linker does not fix the references per se, but instead performs a permanent dynamic link. The compiler and the loader assign a numeric identifier to every procedure in the program. When a subroutine call needs to be made, the caller loads the identifier of the target procedure into a register and calls a module manager that deciphers the identifier and passes control to the selected routine. As born out by the benchmarks, this method is slow.

MEASURING MODULAS

Each compiler was programmed with updated versions of the Modula-2 benchmark programs written for the previously mentioned articles. (The source code for the benchmarks as they execute under the compilers tested is available on PCTECHline). Here the speed of the compiled code was tested in six specific areas: execution of several empty loops, integer arithmetic, array indexing, procedure calls, block moves, and pointer chaining. The classic Sieve of Eratosthenes was included as a second test of integer arithmetic. The speed of each system's libraries was tested in three ways: calculating a real number, writing to the screen, and creating and disposing of a linked list. (In order to put all of the compilers on equal footing, runtime checking, if available, was turned off.)

Porting the benchmark to each system required minor adjustments to the programs. Each language system has a different interface to the system clock, requiring a modification to the code. In all cases, this was a trivial change.

The compilation speed of each compiler was measured as it compiled its benchmark program. Most measurements were timed by the system clock using batch files. Because the nature of their environments precluded using batch files, the ITC and Pecan products were timed using a stopwatch. The test machine was a standard IBM PC with 640KB memory, a 20MB hard disk, and DOS 3.1 configured with 20 buffers. The actual compiled code was examined with Microsoft SYMDEB by tracing through the various Modula-2 runtime systems to get to the benchmark pro-

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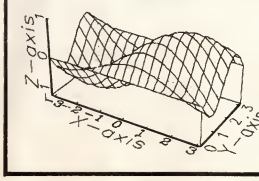

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gram. Pecan's generated code was not traced by SYMDEB due to the presence of p-code in certain library routines; instead, it was disassembled to get an idea of its quality by visual inspection.

For the most part, the compilers performed comparably in the benchmarks. Subtle differences in the code sequences for the benchmarks explain some of the variation, especially in the empty loop test, FOR loop tests, and cardinal arithmetic. In evaluating the cardinal arithmetic and the Sieve benchmarks, the differences in the timings reflect the differences in the code that is generated (refer to figure 2.)

The indexing tests show ITC to be a winner—it makes the best use of the 8086 index registers. The differences between ITC, Logitech, and Workman in this test are due to ITC's improved register deployment and arithmetic expression generation. Logitech reloads its segment registers needlessly during this test, slowing the code down.

In evaluating the subroutine call benchmarks, the differences between ITC and Logitech are slight. Workman's good score reflects the small memory model's single code segment and its 16-bit return addresses, which use less time in transferring control. Modula Corporation does not use the stack as effectively; it dissolves the stack "manually" using five instructions after the CALL, rather than letting the CPU perform the task with one instruction. PCollier, as stated above, uses a dynamic linking mechanism, and copies its parameters from the stack into the called routine's data segment.

In performing a block move when assigning one structure to another, the fastest performers use a REP MOVSW instruction sequence. The PCollier and Modula Corporation compilers use MOVSB, resulting in times that were 50 percent longer. When the results of the pointer chain test are analyzed, they result in a tie between Logitech and Workman's FTL, because FTL uses 16-bit pointers (which are passed around more efficiently). Modula Corporation's compiler calls a runtime subroutine to perform the chaining; moreover, this product implements pointers backward from the Intel standard, which means that the compiler cannot use the 8086's pointer instructions LDS and LES.

Logitech and ITC also did quite well in the floating-point test because they both offer in-line 8087 code generation. Modula Corporation's entry was disqualified when it claimed a spurious floating-point error.

Apart from the Workman FTL, which in the small memory model uses only 16-bit pointers, those compilers adhering to the Intel code model performed the best: Logitech and ITC.

The libraries were tested only briefly. Here the variation in performance is due entirely to library efficiency, affected to some degree by the efficiency of the compiler. The wide variation in performance of the heap management routines (list build and list dispose) is curious. Without the library source code (provided only by ITC), it is difficult to evaluate further.

Interface Technologies Corporation. Ambitious as it was (and in spite of the fact that many bugs present in earlier versions have been fixed), the ITC compiler narrowly misses the mark. ITC markets two versions of its Modula-2 system, the Modula-2 Software Development System, or M2SDS, and SDS-XP. (See the review of M2SDS in Product Watch, Cole Brecheen and Charles Bradford, September 1986, p. 187.) Both products contain the same editor/compiler; the XP version includes additional tools and source code files.

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ITC offers a rich development environment with a windowing syntax-directed editor/compiler. The editor is the first pass of the compiler. Alt-key combinations are used to insert syntactic skeletons, then blanks are filled in. The editor "knows" the syntax of the language: inappropriate statements cannot be entered, meaning that syntax is checked, in effect, during program entry. The editor also controls the formatting of text lines: the user cannot, for example, place two statements on a single line. Program source code is stored in a compressed form, thus speeding the compilation process.

As radical an advance as this editor represents, it is a frustrating tool to learn—knowing where and when to insert a syntactic skeleton takes time to learn. All previous typing and program editing instincts must be discarded.

The editor supports multiple, overlapping windows, and text transfer between windows. Code generation options (for example, in-line 8087 code and runtime error checking) are set via a Ctrl-key combination, and remain in force only for the duration of the development session within a window. To generate object code, the user enters another Ctrl-key sequence and the compiler compiles the program source code to object code. If an error is discovered at compile time, the editor is positioned at the offending line.

Following a successful compilation, the user exits the editing window and calls up the linker, choosing the main program module just compiled from a menu of all compiled modules in the current library. The linker then produces a .EXE file and a symbol map in the user's DOS directory. The .EXE file is fairly straightforward to follow with SYMDEB. Care must be taken, however, when tracing around INT E4H instructions, which ITC uses to implement calls for runtime services. Because the parameters for the calls are placed as data in-line below the INT instruction, the user must not set a breakpoint directly below the INT. Control does not return to the location immediately following the INT, and the debugger's breakpoint instruction will be confused with parameter data.

This compiler is nearly complete in its implementation of Modula-2, up to the second edition of Wirth's book. Monitors cannot be created—this editor simply does not permit the syntax. Definition modules must explicitly export their identifiers. Absolute variables are not allowed, again because the editor does not support the syntax. The compiler recognizes strings as a special type of variable, implemented in Turbo Pascal fashion, by specifying a maximum physical length in the declaration. String logical length is maintained in the first byte of the array, and changes as the string is manipulated.

The code model for the ITC compiler follows the Intel/Microsoft standard model. Parameters are passed on the stack, function procedure return values are placed in registers, and the called procedure cleans up the stack on exit. The ITC benchmark results bear this out—this compiler's performance is clearly in line with Logitech's.

For low-level issues, access to 8086 registers is permitted by importing register variables from the SYSTEM module. The register variables can be included in assignment statements, rather than being accessed as record fields or via procedure calls. SYSTEM also provides a set of routines to access the hardware interrupt vectors. Interrupt service routines written in Modula-2 can be attached to hardware interrupt vectors. In-line assembly language code is

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supported through the pseudo-procedure CODE, exported by SYSTEM. Processes are implemented only as coroutines under ITC Modula-2. No provisions are made for multitasking.

The extensive libraries include Wirth's standard set. Some extra libraries provide screen graphics, including support for region clipping and coordinate transformation, management of the machine's serial communications ports, and ITC's unique file system. The performance of Storage is slow, but it is about equal to Logitech's version.

The XP version includes a make utility and a foreign object code import facility. The latter facility is limited to one code segment; it ignores FIXUPP object records. (FIXUPP records indicate operations emitted by the assembler's instructing the linker to place an address at the designated location. For more about object record formats, see ".OBJ Lessons," Steven Armbrust and Ted Forgeron, October 1985, p. 62.) This limitation renders the facility virtually useless because assembled instructions within an imported segment cannot reference locations within the segment, such as in-line tables.

Additional features to this package are a calculator, an ASCII table, a clock, and a file display utility. The system also has provisions for exporting and importing source code modules to and from DOS as ASCII files.

The system's documentation is good, although it is a bit unorganized. However, the tutorial in the beginning of the manual is a fine introduction to Modula-2 programming.

The ITC system incorporates some novel program development ideas. The editor was one of the first syntax-directed editors used for development on the PC, and it is very efficient. The compiler itself is reasonably fast and compact. Yet, with all it has going for it, this system has problems. The editor hangs occasionally, without warning or apparent reason, and the compiler sometimes generates incorrect code. For example, the statement

```
Boolean := (int > 0);
```

generates erroneous code. Moreover, the compiler yields an "Expression too complicated errors" message for the most trivial of expressions, such as in

```
d := a*b + c*d;
```

which generates an error when the four variables are defined as LONGINTs.

FOR loops with variable steps, illegal in Modula-2, are accepted by the compiler and then generate bad code. Changing the FOR loop index variable is not ignored. (All of the other compilers generate code sequences that preserve the loop variable and restore it with each iteration of the loop.) For example, for the statement

```
FOR i := 1 TO 10 BY k DO
  j := j + 1;
END;
```

the compiler accepts this code, which is itself an error, because no FOR loop can have a variable step. (The **k** was previously declared an integer variable.) The disassembled code is as follows:

```
top: cmp  i,10        ;check loop bounds
     ja   out
     mov  ds, cs:[0]
;get the module's data segment
     mov  ax,j
     add  ax,1
     mov  j,ax        ; j := j + 1
     add  i,4
;ERROR! '4' was pulled out of the air
     jmp  top
```

In the line where the step value is added to the index value **i**, the code

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adds constant value 4 to it. The 4 was not specified in any way in connection with the loop, and it is unclear how the compiler decided to use it. If it had chosen a 0 instead, the code would have gone into an endless loop.

In spite of these seemingly major problems, the M2SDS package is selling well in Europe, where it was not available in its earlier, more flawed, releases. Perhaps in time the product will be improved and make a comeback in the United States as well.

Logitech, Inc. Logitech's Modula-2 appears to be the clear leader in the Modula-2 compiler field (in spite of the fact that it, too, had a number of bugs in its early releases). Also, before its several components were unbundled, Logitech's compiler was an expensive tool for much of the user audience. (See the review of Logitech's "Modula-2/86" in Product Watch, John T. Cockerham, September 1986, p. 187.)

The Logitech system consists of a compiler, a windowing editor, a linker, and a .EXE file creation utility. The compiler is available in two forms: overlaid and fully linked. The overlaid compiler runs in 256KB, and is available with or without 8087/80287 numeric coprocessor support. The fully linked compiler requires 512KB of RAM, but allows more symbols and code space and includes support for an 8087/287 and the 80186/286, a make utility, a windowing environment, and a source-level runtime debugger. Other optional features to the product are a text windowing library, a ROM package, and a Turbo-Pascal-to-Modula-2 translator.

The Logitech editor is an impressive one, supporting multiple windows and files. This editor has some awareness of Modula-2 syntax; it knows, for example, that it must indent after certain statements have been entered onto a line. In addition, a syntax checker that can be invoked from the editor via a function key reports lapses in indentation style. Both the compiler and linker are invoked via a function key as well, and the compiler passes error location information back to the editor for positioning of the cursor.

This system's source code files compile into .LNK files that the linker processes into .LOD files. These .LOD files can be converted by a utility into .EXE files; otherwise, the user can call the runtime system M2.EXE to load .LOD files and execute them. The compiler generates listing files by the user setting a switch on the command line. In addition, .REF files are produced for use by the debugger.

The code model appears to be an implementation of the full Intel/Microsoft standard. Procedure activation records are implemented through the use of ENTER and LEAVE instructions when compiling to an 80186/286. The code is very fast, as evidenced in the results for the benchmark tests. In looking at the code using SYMDEB, however, the compiler appears to reload its segment registers more often than is necessary simply because the compiler has no mechanism to detect that correct values are already there.

Both versions of this compiler support the definition of Modula-2 as outlined in the second edition of Wirth's book; the third edition was published after the compilers were released. (Logitech is reportedly preparing an update to meet this most current specification.) Even so, the only significant difference between the compiler and the current definition of the language is the compiler's requirement that definition modules explicitly export their identifiers. The system's low-level facilities are complete, with absolute addresses for

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variable, interrupt access, in-line code generation, and CPU register access.

Logitech's libraries are quite extensive and provide binary-coded-decimal (BCD) support, interrupt handling, DOS services, random file I/O, a mouse interface, multitasking, and serial device handling. Notably absent, however, is screen graphics support.

This package offers the user three options for debugging. First, in the basic system, an execution error simply produces a RAM dump. A postmortem debugger interprets the RAM dump and pinpoints the error. Second, the library module Debug, if imported, traces the stack. Finally, a powerful runtime debugger is also available.

The Logitech documentation is well done. The manual is now perfect-bound and includes a brief tutorial on the language. The index is complete, and the definitions of the libraries are reprinted in the manual for easy reference. In short, this is a very good compiler and a leader in this field, but it is in need of some minor burnishing.

Modula Corporation. For a long time the source of a p-code (pseudocode) implementation of Modula-2, this company has recently begun to produce a native code implementation for the PC, called PC Modula-2. The system includes a compiler, a loader, and a linker; a windowing, source-level debugger is available at extra cost. However, an editor is not offered with this product.

The compiler is invoked from DOS; its output is a .RLX file containing the relocatable object code, and a .RFC file with information for the debugger. The compiler error messages are terse,

In its code model, the Modula Corporation compiler limits procedure parameter lists to 16 words, which can cause some problems.

but adequate. The user can control runtime checking through the use of switches on the command line.

The language that is implemented by this compiler conforms to the third edition of Wirth's report: definition modules do not have to export their identifiers explicitly, priority modules and multitasking are available, and strings are not a predefined type of the language but are arrays of characters terminated by a null character.

This system's low-level facilities include CODE procedures (which are short in-line assembly language routines), implementation modules written in assembly language, absolute addressing, and I/O device management. Note, however, that the assembly language-level implementation modules must follow a rigid format in order for the linker to load them properly.

The code model for the Modula Corporation compiler is not the Intel/Microsoft standard. The compiler limits procedure parameter lists to a total of 16 words in length, which can be a problem—open arrays require 3 words of parameter space for the address and the size of the array, VAR parameters require 2 words for the address, and value parameters require as many words as their base types are large.

This Modula-2 compiler does not use the RET instruction to return from a subroutine. Instead, the compiler emits an indirect jump instruction, taking its destination address from the stack at the point where the CALL instruction had placed the return address, and leaving the calling routine to clean up the stack. The performance overhead exacted by this process is evidenced in the procedure call benchmarks.

The results for these tests can be puzzling without the knowledge that this compiler was ported from another machine and, more significantly, that the chosen code model underemploys the instruction repertoire of the 8086. This is evidenced by the fact that the Modula compiler stores its pointers with the segment portion in the low-order word—in reverse of the Intel standard. This prevents the compiler from using the pointer loading instructions, LDS and LES.

The generated code is also inefficient at times. In setting up a CASE statement, for example, the address of the selected code is loaded from the jump table into a register and a jump is taken relative to the register rather than out of the table itself.

However, the balance of its scores in the benchmarks are very good. This compiler turned in the shortest time for the cardinal arithmetic test. (During the real number test, though, the library halted execution of the benchmark with an error message claiming an attempted conversion of too large a floating-point number into an integer. It is unclear why **sqrt(sin(ln(pi)))** would require an integer conversion at all, even for an intermediate value.)

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The libraries for this compiler include Wirth's standards and are otherwise comprehensive. In addition, the system supports multitasking, string management, graphics, and long sets (those with 65,534 elements). The debugger is an interesting one, with multiple screens that permit the user simultaneous examination of the stack, global variables, and registers. The Modula Corporation documentation is very thorough and well indexed.

PCollier Systems. This consulting firm has produced a very compact implementation of the language. The Modula-2PC package includes compiler, editor, and linking loader. The editor is a standard full-screen utility with its own set of keystroke commands that are unlike any other and do not use the PC's function keys. It communicates with the compiler through the DOS environment; error information is passed back to the editor for cursor positioning.

The language implementation is complete as specified in the third edition of the language report. The WHILE statement is extended to permit multiple Boolean expressions and statement sequences. For example, in

```
WHILE
  (negative) DO j := j + 17 |
  (i > 0) DO j := j – 17
END
```

the control sequence loops through conditional expressions until the first true expression is encountered. Its associated statements are executed, then control returns to the top of the WHILE loop. The loop terminates when all of the conditional expressions are false.

PCollier's low-level facilities are adequate. Its CODE procedures are macros for small sequences of machine instructions. Once defined, these CODE procedures can be invoked simply by naming them; they will be expanded into in-line code at that point in the program. The CODEGEN pseudo-procedure, however, is closer in concept to Turbo Pascal's INLINE statement, and permits the generation of lengthy assembly language sequences. External .COM files can be included in the object code using the LOADASM procedure. Register access in Modula-2 statements is not allowed. Software interrupts can be called through a procedure imported from the DOS module.

The real number support provided by the system depends upon which of two included versions of the loader is used to create the program: one uses the 8087 coprocessor, the other does not. The 8087 "detect or emulate" decision cannot be postponed until runtime. The loader will dynamically link to imported modules as they are called; it also can generate a .EXE file.

The code model for this compiler differs from the Intel/Microsoft standard. First, the process of calling procedures is handled by a global module manager. The manager is passed a key for the requested module. The targeted procedure is located and control passed to it. If the targeted procedure is not present in RAM, it is located on disk and loaded. Second, arguments are passed on the stack to the module manager, which then removes the parameters from the stack and places them into the data segment for the routine. If a recursive call is made, the previous invocation's data segment is preserved and the current set of parameters is instantiated. This is not very efficient, as the benchmarks show.

The code generated by this compiler for handling Boolean expressions inside IF statements is different from most compilers. This generated code calculates a Boolean value for the expression and tests it against TRUE, jumping on the result of the comparison. The calculation requires one set of jumps; the test is an additional set. This is a less efficient method than that of the other compilers, which emit direct comparisons and jumps.

PCollier's arithmetic code is also less efficient than that of the others. Modula-2PC uses the 8086's BX register for interfacing to RAM. Note (in figure 2) the two MOV instructions at the end of the code: one moves the result into BX, the other moves BX into RAM.

The libraries for this compiler are complete and include a nice screen, window, and menu management module. The Terminal module, however, does not follow the standard: Terminal.Read takes its first input from the DOS command line. Coroutines are supported, but multitasking is not.

Clearly, the strength of the PCollier implementation is its documentation. The book is exceptionally well written and indexed. With its fine tutorial, it easily could retail as an introduction to Modula-2 on its own.

Pecan Software Systems, Inc. This company acquired Volition Systems and subsequently upgraded and rereleased Volition's Modula-2 product under its own label. Pecan Modula-2 operates in the Power System environment, Pecan's new name for the UCSD (and later SofTech) p-System, a virtual machine environment that has existed since the mid-1970s. This compiler is invoked from

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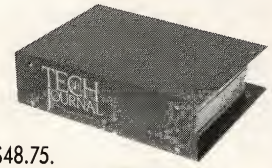

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the Power System and emits either p-code or native 8086 code. The p-code is threaded code for execution by the Power System's virtual machine interpreter. Pecan has ported the Power System and its virtual machine to several different computing environments.

The Power System runs above DOS, but does not use DOS for its file operations. File I/O is performed directly by the Power System, using an antiquated sector system that requires allocating a given number of sectors to a file at the time of a file's creation. Deleting a file on a Power System virtual volume leaves a "hole" of unused sectors the same size as the deleted file. When many create and delete cycles occur on a volume, it can become extremely fragmented, and free sectors need to be collected into a single block by an operation called Krunch.

The editor is a fairly standard text entry model. Provisions are included for editing multiple files, with text transfer between files, function key macros, and automatic indentation. This editor can perform source code logging, which automatically inserts a comment into the source file, containing the date and a line of explanation for changes to the program source code.

Unlike UCSD Pascal, Pecan's Modula-2 editor does not have an interface to the compiler; therefore, the user must save the work in progress and exit the editor before invoking the compiler. Compile-time errors are not communicated to the editor for cursor positioning in the source file.

The compiler accepts standard Modula-2 syntax according to the third edition of Wirth's report, including module priority. Errors are correctly spotted and the associated messages are informative. Compiler options are embedded as comments within the text of the module being compiled.

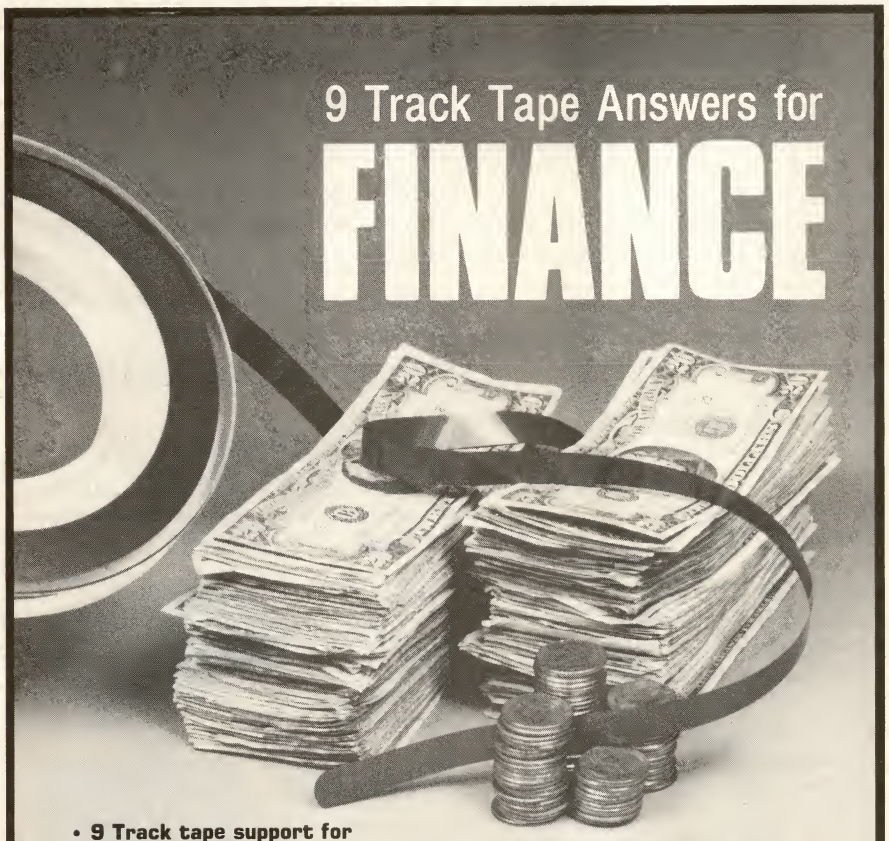
Pecan has added several extensions to the Modula-2 language in this implementation, mostly to accommodate features of the Power System. BCD variables are supported and are defined using the predefined type PACKED. Function procedures may return any type as a result, including RECORDs.

However, some restrictions cloud the differences between CARDINAL and INTEGER variables. For example, cardinal division cannot be performed when an operand is greater than 32,767. Similarly, case labels that are of type CARDINAL cannot exceed 32,767.

This system's low-level facilities are geared toward p-code: no direct access to the host system is allowed. The user can generate p-code routines using several pseudo-procedures.

In its default mode, this compiler directly emits p-code into Power System .CODE files for implementation and program modules. Definition modules compile to .SYM files, which provide the necessary symbolic information to the compiler when the module is imported. The native code generator is invoked by setting a compiler directive option. Configuring the Power System for an 8087 requires changing the name of the default code generator and Power System runtime library files. Once so configured, the 8087 is required to be present for a floating-point program to run; otherwise, the program will hang the computer.

The performance of the native code generator can be seen in the benchmark results and in figure 2. This compiler, like the PCollier product, actually calculates a Boolean value for simple comparison expressions, then tests the state of the Boolean value, rather than simply comparing the two operands and branching on the state of



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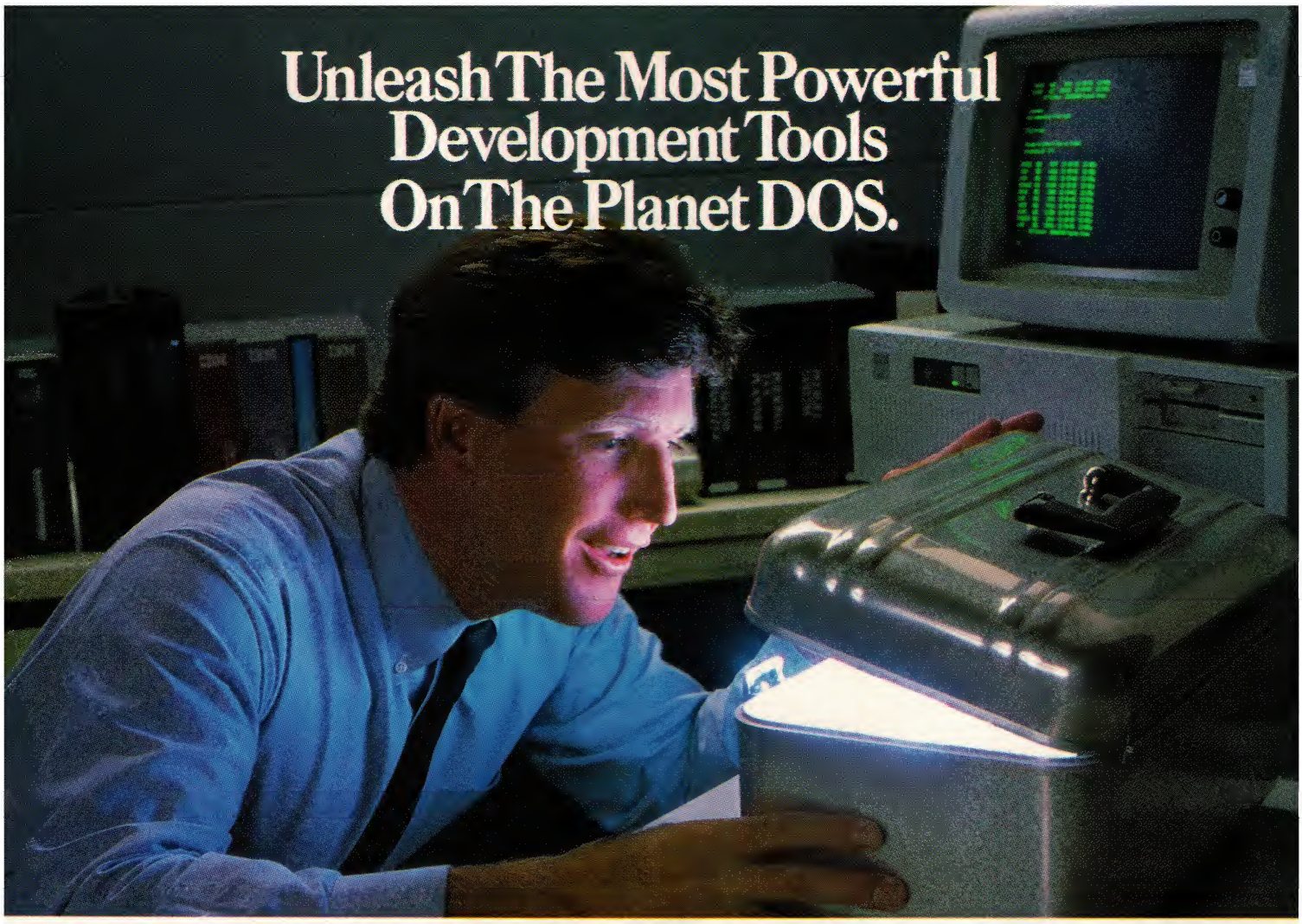

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the flags. For example, the code generated for IF i > 0 THEN ... is

```
    xor  ax,ax
    mov  dx,i
    cmp  dx,0
    jnz  notzero
    inc  ax
notzero:
    shr  ax,1
    jc   truepart
    jmp  falsepart
truepart:
    ...
```

The result in inefficient code, due to the fact that the native code generator is directly translating individual p-code operations into 8086 machine code. The native code generator never "sees" the source code and thus is unable to generate code specific to the larger program context, such as an IF statement.

The Pecan libraries provide most of the standard Modula-2 functions, and multitasking and coroutines are supported. Decimal arithmetic on BCD variables is an additional feature. Note in the benchmarks that this system ran out of heap space when executing the linked list creation test.

The porting of the benchmark programs was more difficult on this system than on any of the others. Its Time function is undocumented; but experimentation revealed that the resolution of the clock was in 60ths of a second. Thus, the benchmark times are the result of dividing by 60 the actual times turned in by the compiler.

The Pecan documentation is good, and the index is thorough, but it presupposes a working knowledge of Pascal. Although the coverage of the libraries is adequate, some lapses undercut its overall effectiveness. The format of Time and a description of the actual representation of strings are absent.

Clearly, a restrictive aspect of Pecan Modula-2 is the Power System. Although truly portable, it is annoyingly different from DOS.

The worst aspect of working in Pecan Modula-2 is the Power System itself. Although truly portable, it is annoyingly different from DOS. For example, the screen clears, rather than scrolls, between programs. This inhibits the screen from acting as short-term storage for program results across several program invocations. The user interface is about as clumsy as that of DOS—one-character commands—but without many of the redeeming features of DOS, such as default path specifications, command line parameters to programs, and automatic file maintenance.

The strength of the Power System lies in the diversity of machines to which it has been ported. With Pecan Modula-2, true portability can be achieved if the programmer limits himself to the high-level features of the language. For low-level applications, the p-code degrades program performance and limits programmer options.

Workman & Associates. The Australian-born FTL (faster than light) compiler is distributed in the United States by Workman & Associates. This powerful compiler comes with a useful editor, an assembler, and a linker. A memory-resident debugger is an added feature.

As in Turbo Pascal, the compiler and the editor can both load and remain resident during an editing session. The compiler retains .SYM symbol table files in memory, speeding compilation. (.SYM files are the result of compiling a definition module.)

The editor itself can be configured to use either Micropro's WordStar or Unipress Software's Emacs control key sequences for commands. The user can set up keyboard macros, but language constructs cannot be inserted by Alt-key combinations, as they can be in the ITC editor. The editor is limited to three fixed-size windows containing up to three simultaneously opened files. The user can set compiler options from a screen in the editor, and the compiler can be called up quickly. The linker is easily accessed from the editor as well, but promptly runs out memory in all but the largest machines.

The compiler is (as claimed) very fast, with a compile time benchmark of 13 seconds. This one-pass system generates code for a small memory model: 64KB of data and 64KB of code. The compiler output is in the form of .SMR files, which are fed to the linker. The code it generates is reasonably tight, and the times for the FTL compiler in the benchmarks reflect the advantages of the small memory model. The code model is similar to Intel/Microsoft: Parameters are pushed onto the stack from left to right. The called procedure cleans up the procedure activation record. Functions return their results on the stack rather than in registers. CASE

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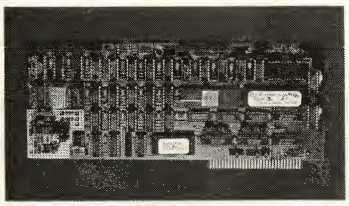

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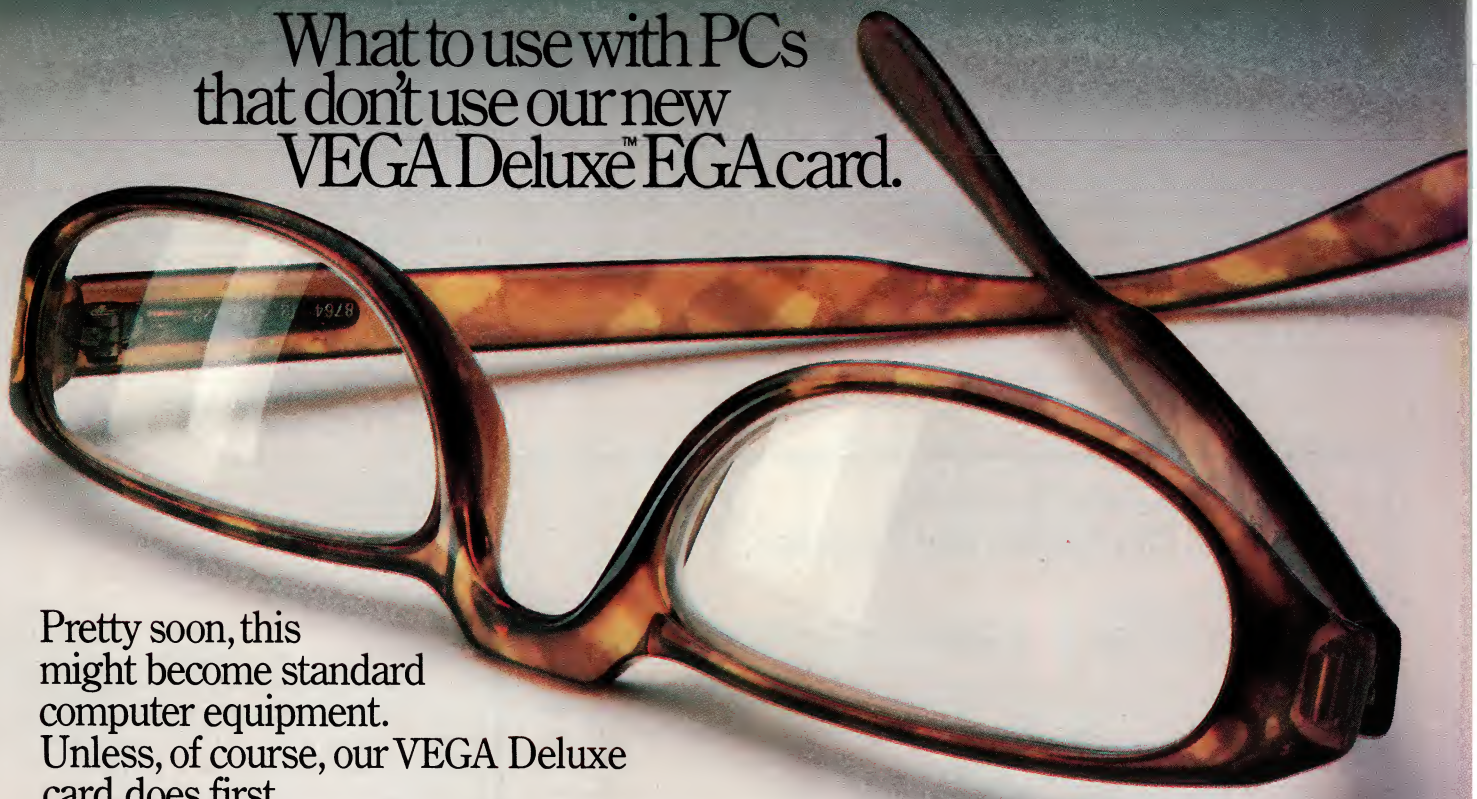

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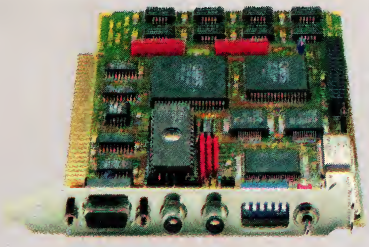

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statements are implemented as a series of comparisons and jumps—a result of the compiler being one-pass.

FTL provides runtime checking facilities that can be disabled through the use of a compiler switch. The compiler will supply additional information to the linker for creating a procedure map that contains offsets of procedures into the generated .COM file.

This compiler would not accept a priority specification for program modules. It did, however, accept and compile correctly several lines of Modula-2 that were not separated by semicolons. The compiler checks several environment strings governing the search paths, default extensions, and the directories to place output.

An assembler is included for generating low-level routines. The assembler generates code for the linker and supports pseudo-operations that allow the assembled module to import symbols from FTL .SYM files. No facilities are available for generating in-line machine code. The linker optionally displays a symbol map to the console. The user must redirect linker output in order to capture this map. A .COM file is produced, which is very easy to trace through using SYMDEB.

ADDRESS variables, WORDs, and BYTEs are available from the definition module System. The library module MSDOS contains the routines for accessing the system BIOS interrupts, and calling for DOS services. Registers are supplied to these routines as a record. Other FTL library modules include Storage, for heap management; Processes, for multitasking and process synchronization; Streams, for file streams; Terminal, for terminal I/O; Command, for command-line processing; CallProg, for program spawning; Maths and Solve, for floating-point operations; GetEnvName, for environment strings; and Strings, for string manipulations. The performance of the heap manager seems very impressive, but it has very little heap to manage.

The two manuals included with this package are thin, but well written. One is a description of CP/M implementation of the language, but it includes a reasonable introduction to Modula-2. The other describes the DOS version of the system, and makes frequent references to the CP/M manual.

The source code for the editor is available at extra cost. Despite the limitations of the small model, this compiler is a good value and offers an adequate introduction to the language.

MODULAR DIRECTIONS

The six compilers reviewed here present the project manager with a variety of choices. If portability across a number of machines is important, the obvious choice is Pecan, in spite of the drawbacks of the Power System and p-code. If a manager is designing for PCs alone, then the Logitech system or the Modula Corporation compiler fits the bill. For first-time Modula-2 users, the FTL and the PCollier compilers provide excellent introductory documentation and are reasonably priced. The jury is still out on the ITC product, but it is bound to improve.

Their overall quality notwithstanding, none of these compilers puts Modula-2 in a position to challenge the supremacy of C in PC programming (yet). Only when these products allow foreign object code integration, using the Microsoft standard, will Modula-2 begin to take its true place in the PC market. In another direction, a Modula-2 compiler that incorporates Microsoft Windows capability would, of course, prove a noteworthy step. The development of

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MODULA-2

a Windows application, with its large library of routines and lengthy header file, would be speeded up considerably by taking advantage of Modula-2's separately compiled modules. The strength of this language is in its ability to spot type mismatches in procedure calls—this is a situation that often generates runtime errors in C.

Modula-2 represents the future in large-scale programming—the development of a standard is important. The software engineering features that it contains are shared only by Ada. Given the expense of creating software, it seems inevitable that Modula-2 will become the language of choice for many software developers.

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John T. Cockerham, M.D., is a cardiologist at The Children's Hospital in Boston and is on the faculty of Harvard Medical School. His most recent articles for PC Tech Journal *were "Evaluating the EGA: The EGA Standard," October 1986, p. 48, and "Evaluating the EGA: The EGA Spectrum," October 1986, p. 80 and November 1986, p. 147.*

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The new Clipper also sports Expanded Memory support, additional functions and improved memo fields. The new release, dubbed Autumn '86, is not copy protected.

Clipper Autumn '86 is available for a suggested retail price of $695. Registered users of Clipper may upgrade to the new version for $139.

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The CodeView™ debugger, free for a limited time, uses windows to show everything on one screen: source alongside disassembled object, variables, stack and registers. Drop down windows—use a mouse if you like—obviate learning of commands. "A source-level debugger that puts the rest to shame" (Dobb's),

Microsoft C now has five memory models for code and data, plus non-library support for another thirteen, and boasts alternate math packages for speed versus accuracy, with or without 8087/80287 chips. A big plus in multi-language settings: call from this C any routine written in later versions of M'soft Pascal, FORTRAN, or Macro Assembler. Object code of all four may be intermixed come link time or commingled into libraries.

Both linker and library manager are part of the package, as is the "make", a UNIX™ name for a smart batch program which knows to expend minimum effort to rebuild any size of project by compiling and assembling only elements affected by new or changed modules.

It is reportedly used by Lotus, Ashton-Tate and, fittingly, Microsoft itself to develop Windows. Dobb's calls it "the best MS-DOS C development environment value today [for] virtually any kind of program conceivable." 320k suggested.

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Curses from Lattice™ manages the screen of the PC like Unix™ curses. Library of 84 functions and macros parallels Unix with matching parameter lists. So Unix programs are at home on the PC, and vice versa. Keeps any number of screens in memory, supports color, vast function set to get characters, wrap lines, scroll, blank lines, highlight, etc. Like Unix refreshes screen only on your command. Ask for: L0850. List: $125. Here: $99. With Source: L0860, $250/$199

dBC *Lattice Library Maintains dBASE Compatible Files With the Power and Speed of C*

dBC™ links C to dBASE. It creates and maintains files and their indexes which exactly replicate dBASE file design. So dBASE can read and update them. And the reverse. dBC can use any files created by dBASE. Now C and dBASE can operate on the same data bases interchangeably.

That opens up the widespread culture of dBASE installations to exploitation by C programmers. Tap that market, avoid the resident dBASE language, and gain the advantages of C with this single product.

dBC's functions parallel all dBASE's file handling commands, many decomposed to give closer control. Each backed by demo source files on disk.

Use dBC for custom work for clients, or on its own. It's a complete ISAM file manager for C whether or not dBASE will be used in tandem, supports all four memory models, and can have sixteen index and data files open. Big discount to buyers of both dBASE II and III versions. Specify Lattice, Microsoft 3.x, or DeSmet.

Versions:		List:	PC Brand:
L00II	For dBASE II	$250	$195
LCCII	With Source	$500	$390
L0III	For dBASE III	$250	$195
LCIII	With Source	$500	$390

PANEL *Feature-Laden Screen Design Tool*

Writing your own screenware can blow completion dates and profits. Panel™ works with you interactively to set up foolproof screen displays and data entry forms rapidly. Output is C source code.

Not just single plane: layer your screen designs with up to ten overlapping images: Background pop-up lists, help boxes, and alternate input fields.

Panel builds in a user interface for keystroke movement within and between fields, supplies validation routines for checking user field entries. Diverse attributes may be selected for any field — size, data type, color, conversion of input to upper case; clearance of existing data when new entry is started; masks for standard formats (eg, dates); phrases which fill in when their first letter is typed; multiple-choice lists from which to choose by cursoring a highlighted bar. Fields may be multi-lined and scrolled if larger than the screen space allotted them. Specify: S0400 & Compiler. List: $295, Us: $229

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GREENLEAF FUNCTIONS *Bountiful Harvest*

C source, assembler source, and binary libraries of 225 functions for many compilers. Emphasizes tight functional groupings to minimize loading code which your application may never use. Manual helps select functions, bulletin board, too.

A sampling: *DOS* extensions for file and directory manipulation; *Screen:* to select mode, page, monochrome or color, palette; cursor shape, positioning; clearing and scrolling; pixel get and put; read light pen. *Strings:* Center, justify, etc.; efficient list operations which add, delete, sort string pointers for top speed. *Other:* graphics character primitives, keyboard status, function key assignment, time/date, read registers and memory size, peek and poke. Mature best-seller. Specify: S0770 & Compiler. List: $185, Here: $139

GREENLEAF COMMUNICATIONS *Hello World*

Want your application to communicate with other users or remote date bases by asynchronous communications built right into your C programs! Even if you don't need it now, that's a skill to have at the ready!

120 functions *and demo programs in both C and assembler source code* set up separate transmit and receive ring buffers for up to 16 simultaneous channels. Interrupt driven so you can halt an incoming record, display it, file it, let the user edit it, then continue. Goodbye separate communications software.

Supports up to 9600 baud, ASCII or binary, any parity or word length, 8250 UARTs, Xon/Xoff and Xmodem, WideTrack receive. Specify: S0750 & Compiler. List: $185, Us: $139

INTERACTIVE-C

Compiler-Compatible Interpreter, Editor, Debugger

Earlier C interpreters were miraculous compromises. Interactive-C shows how far C interpreters have come. More than an interpreter, Interactive-C is a fully-integrated development environment: a complete K&R interpreter bound tightly to its own editor and debugger.

Slice through programming projects like a hot knife through butter. Extensive error-checking insures immediate detection of program misbehavior. State of the art debugging tools include breakpoints, watchvalues, several stepping options and interactive viewing and modification of variables. An Interactive-C exclusive lets you interrupt to edit and "continue" from where you left off. Eliminates plodding replays of already debugged code—the ball and chain of other interpreters.

Operate Interactive-C using adjustable edit, command, and status windows. Toggle a second screen showing only your program's output—never any crowded intermixing. Or, boost productivity with twin CRTs. Load object code of functions you have already compiled. Or of commercial libraries. Interactive-C has immediate mode, syntax checking both as you type and run, and cursor positioning precisely pointing at an error, not possible with incremental or pseudo-compilers which leave source code behind.

100% compiler compatible—right down to header files and library calls. Port programs between Interactive-C and your compiler with no modifications whatever—not even tricky areas of dynamic memory allocation and I/O.

Specify:	List:	PC Brand:
E950 & Compiler	$249	$219

DAN BRICKLIN'S DEMO PROGRAM

Storyboard Your Program

The Legendary One has created Metaphor Two when the rest of us are still on Zero. Dan's first was the original electronic spreadsheet (VisiCalc™). This one is for programmers.

Words don't express program ideas because programs are screens! Dan's Demo creates slide shows. Create a screen — a snapshot of your planned product as it runs. Anything goes: words, borders, box rules, inverse and underlining of monochrome, fore- and background color. Copy this "slide" to an empty screen. Change it a little, to show the next instant of run-time. Do it again. Presto, a whole slide show of your program in action.

All 250 characters and attributes are available from scrollable lists which pop to the screen. All commands are layered in Lotus-style pop-up menus. Frequent choices mapped to function keys as well. 80x25 character mode, not bit-mapped.

Screen areas can be blocked for cut and paste or filled with color or characters, even blink. Slides can overlay on others, can be shuffled, deleted. Slides can proceed at time intervals or branch anywhere in the slide sequence depending on user keyhits.

Invaluable to prototype the program you are about to write, to position the labels, choose the color decor, smoothe out the keystroke interface. Or load the "capture" utility and snapshot the screens of any running program for an instant slide show.

Each copy entitles you to redistribute fifty of the slide projector program that runs demos. Plain manual, no binder keeps price of big product small. "Might . . . become *the* essential tool in . . . user interface prototyping," *Tech Journal*. Ask for: N0100. List: $75 US: $69

BASTOC *OPTIMIZES!*

Translates BASIC Into C

For a trifling price, BASTOC™ moves truckloads of BASIC code over to C. It's a translator which takes in Microsoft Extended BASIC and emits pure K&R C for Lattice 3.0. It will optionally convert your program into a single monolithic C function or decompose it into separate functions, one for each GOSUB label.

Version 2's optimization dramatically reduces execution time. Converts to integers those variables in BASIC programs which do not need floating point. Where BASIC uses full assignment statements to increment counters, BASTOC converts to C's compact form. Strings dynamically allocated ridding your application of BASIC's catatonic halts for garbage collection. Creates structure of even convoluted BASIC code. Huge worksaver.

Ask for:	List:	PC Brand:
S0375	$495	$399

Shopping List for the Power Workbench

	LIST	US
ASSEMBLERS & DEBUGGERS		
Advanced Trace-86 *Morgan, ASM Interpreter*	175	119
Codesmith-86 *Dubugger by Visual Age*	145	99
CSD Debugger *C source level by Mark Williams*	75	55
C-Sprite Debugger *by Lattice, source level*	175	139
Microsoft Macro Assembler *with Utilities*	150	109
PASM86 *by Phoenix, Macro Assembler*	195	125
Periscope I Debugger *Data Base Decisions*	295	235
Periscope II *Data Base Decisions*	129	99
Periscope II-X *software only*	115	74
Pfix86 Plus *by Phoenix, Symbolic Debugger*	395	235
BASIC LANGUAGE		
BetterBASIC *Summit Software*	195	165
BetterBASIC Utilities *8087 Math Support*	99	85
Btrieve Interface	99	85
Run-Time Module	250	225
Microsoft BASIC Interpreter *for XENIX*	350	295
Microsoft QuickBASIC Compiler *full BASICA*	99	79
Professional BASIC *by Morgan*	99	69
True BASIC *True BASIC Inc*	150	99
Run Time Module	150	99
True BASIC Libraries *Btrieve, Asyn, Sort, etc.*	Var	Call
C COMPILERS		
C-86 Compiler *Computer Innovations*	395	289
Lattice C Compiler *from Lattice*	500	299
Let's C Compiler *by Mark Williams*	75	55
with CSD Source Level Debugger	150	105
MWC-86: Mark Williams C Development	495	369
Microsoft C Compiler *4.0*	450	295
C INTERPRETERS		
C-Terp *by Gimpel Software*	300	249
Instant C *by Rational Systems*	500	395
Interactive-C *by IMPACC with debugging*	249	219
RUN/C Professional *from Lifeboat*	250	185
RUN/C *without Loadable Libraries*	120	109
TEXT EDITORS		
Brief *from Solution Systems*	195	Call
Edix *by Emerging Tech...Multi-screen*	195	159
Epsilon *by Lugaru Software, like EMACS*	195	149
FirsTime *by Spruce Technology, C syntax*	295	229
Kedit *by Mansfield, similar to Xedit*	125	99
LSE, the Lattice Screen Editor *Multi Window*	125	100
Pmate *by Phoenix, with Macros*	195	115
Text Management Utilities *Grep, splat, diff, etc.*	120	100
Vedit *by Compuview*	150	99
Vedit Plus *by Compuview*	185	129
FILE MANAGERS		
Btrieve *by Softcraft, no royalties*	250	195
Btrieve Network *by Softcraft*	595	465
C-Tree *by FairCom - no royalties, source*	395	329
R-Tree *by FairCom-Report Generator*	295	245
C-Tree & R-Tree Combo *by FairCom*	650	541
dBC *dBASE file manager from Lattice*	250	195
with source	500	390
dbVista *single user DBMS by Raima*	195	139
with source	495	399
dbVista *multi-user DBMS*	495	399
with source	990	815
Opt-Tech Sort *Can sort Btrieve files*	149	105
SCREEN DESIGN		
Curses *by Lattice, UNIX screen designer*	125	99
with Source	250	199
Greenleaf Data Windows.....*New*	225	169
with source	395	297
source purchased later	225	169
On-Line Help *from Opt-Tech Data*	149	105
Panel *by Roundhill, no royalties*	295	229
View Manager for C *by Blaise*	275	189
Vitamin C *by Creative Programming*	150	129
Windows for C *Vermont Creative Software*	195	149
Windows for Data *includes Windows for C*	295	259
ZView *Data Management Consultants*	245	175
GRAPHICS		
Essential Graphics *by Essential, no royalties*	250	210
GSS Graphics Development Toolkit	495	375
GSS Kernel System *by Graphic Software*	495	375
GSS Kernel System *for IBM RT*	795	645
GSS Metafile Interpreter	295	235
GSS Plotting System	495	375
Halo *by Media Cybernetics*	300	219
with **Dr. Halo II**	440	299
Halo for Microsoft *includes all fonts*	595	434
COMMUNICATIONS		
Asynch Manager *by Blaise, for C or Pascal*	175	125
Greenleaf Communications *by Greenleaf*	185	139
PTel *by Phoenix, Binary File Communicator*	195	115
Software Horizons Pack 3	149	119
UTILITY LIBRARIES		
Blaise C Tools Plus	175	125
Blaise C Tools	125	89
Blaise C Tools 2	100	69
C Food Smorgasbord *by Lattice*	150	109
C Utility Library *by Essential, 300 functions*	185	139
Greenleaf Functions *by Greenleaf Software*	185	139
PforCe *by Phoenix, vast library*	395	235
Software Horizons *Packages*	Var	Call
TopView Tool Basket *by Lattice, source avail*	250	199
DEVELOPMENT TOOLS		
Code Sifter *by David Smith Software, Profiler*	119	89
C-Worthy *by Custom Design Software*	295	269
C-Worthy for Network *Menus, help, errors*	495	449
Dan Bricklin's Demo Program *Prototyper*	75	69
LMK from Lattice *by Lattice, "make" like UNIX*	195	149
Microsoft Window Development Toolkit	500	365
PC-Lint *by Gimpel Software, after UNIX's "lint"*	139	125
PFinish *by Phoenix, EXE performance analyzer*	395	235
Plink86 Plus *Utilizes memory for overlays*	495	325
Pmaker *by Phoenix, like UNIX "make"*	125	85
Pre-C *by Phoenix, UNIX "lint"-alike*	295	155
Pfantasy Pac *six Phoenix products*	1295	875
OTHER TOOLS		
BASTOC *by JMI, convert BASIC to C*	495	399
BASIC-C *BASIC's functions added to C*	175	139
The HAMMER *by OES Systems*	195	139
Report Option *by Softcraft, Btrieve Report Gen.*	145	128
Xtrieve *by Softcraft, Query Utility for Btrieve*	245	220
FORTRAN COMPILERS & UTILITIES		
ACS Time Series *by Alpha Computer Service*	495	405
Forlib- Plus *by Alpha Computer Service*	70	45
Microsoft FORTRAN *Links with Microsoft C*	350	219
Microsoft FORTRAN *for XENIX*	695	546
RM/FORTRAN *by Ryan McFarland*	595	Call
Scientific Subroutine Package *by Alpha*	295	239
The Statistician *by Alpha Computer*	295	239
Strings & Things *by Alpha Computer*	70	45
OTHER LANGUAGES & UTILITIES		
Microsoft COBOL Compiler	700	499
Microsoft COBOL Compiler *for XENIX*	995	795
Microsoft COBOL Tools *with Source Debugger*	350	259
Microsoft COBOL Tools *for XENIX*	450	333
Microsoft Lisp *New Common Lisp*	250	189
Microsoft MuMath *includes MuSimp*	300	199
Microsoft Pascal Compiler *Links with M'soft C.*	300	199
Microsoft Pascal Compiler *for XENIX*	695	546
PDisk *Phoenix's new disk manager*	195	125
RM/COBOL *by Ryan-McFarland*	950	Call
RM/COBOL 8X *ANSI 85 COBOL*	1250	Call
Source Print *Aldebaran's diagrammer*	139	109

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A Mighty Fortress Is Their FORTRAN

Picking over features of rival products is not necessary if FORTRAN is your need, still the citadel of scientific and engineering work. Ryan-McFarland has left the competition battering at the gates.

RM/FORTRAN™ is a complete implementation of FORTRAN-77 (ANSI X3.9-1978), the only PC FORTRAN certified by the General Services Administration at the highest test level. The reason: it's a big mainframe compiler moved to PCs, with the bonus that mainframe and mini applications can wander between environments.

Now, on your PC, you can develop large applications, with programs up to 640k (bigger using overlays), arrays over 64k, and using a long list of VS, VAX and FORTRAN-66 extensions you may have grown fond of — long symbolic names, "include", IRT bit functions — because R-M has left out nothing.

But what really sets RM/FORTRAN apart is optimization. The compiler reduces the number of instructions to the minimum which will actually execute, and even takes advantage of each processor's features to deliver lightning-fast object code. It runs 30%-40% faster than Microsoft 3.2, and could make your mainframe not worth the trouble.

Comes with an interactive symbolic debugger like that accompanying IBM VS FORTRAN, Plink86 subset, has a cross reference compile option, supports assembler and C subroutine calls, IEEE floating point, 8087 and 80287 chips.

"Compiler's documentation, ease of use, speed of execution, and debugger facilities place it first for recommendation" said the *Tech Journal* (10/85).

R-M has been writing FORTRAN compilers for IBM, DEC, etc. for 20 years. There is no greater expert.

Ask for:	List:	PC Brand:
I0300	$595	Call

RUN/C PRO

C Interpreter Links Binary Libraries

Run/C comes in an apprentice and pro version. The professional model dynamically loads and unloads multiple binary function libraries like C-Food Smorgasbord™ and Halo Graphics™ — potentially any library compiled with Lattice's large model. Inside this interpreter your C program can reach for functions in the best of commercial libraries.

This C interpreter behaves like PC BASIC meets WordStar® . Use fullscreen editing to create a program. RUN it. If it stumbles, LIST it, EDIT it, RUN it again, fix it again. Use familiar commands like LOAD, MERGE, SAVE, FILES, even TRON and TRACE.

Ideal for program development. Put up code at high speed, try out things devil-may care, let RUN/C find your malaprops. Blast away until tight little code segments are undyingly faithful.

Manual shows how to develop the interface to a commercial library, using the Lattice compiler (a must!). Link your own function archive the same way. (320k minimum; 512k recommended to fit libraries.)

Ask for: S0950 List: $250 PCB: $185

ZVIEW

Screen Design Aid

A complete package for screen design with full windows management as a bonus! Easy creation of screens with complex validation, such as range checking or required/optional data. Powerful Screen Paint utility for creating or editing applications screens. Built in security levels, set at run-time, control read or read/write access by field or screen. Automatic help screen processing for run-time aid per field or screen. Applications regain control during field tabbing, allowing run-time on-screen transaction processing or flow control. Run-time functions include Screen Read and Write with automatic transparent data conversion from screen image to data storage, Field Editing, Help Screen Processing, even a capability to change any field characteristic at run-time, plus Window Push Pop and Scroll. Versions for Lattice, Microsoft and Aztec C. Automatic free updates to registered users. No run-time royalties.

List: $245 PC Brand: $175

LATTICE C COMPILER

Major Upgrades to the Best Selling C Compiler

Lattice now embraces key UNIX™ enhancements which have entered the language since K&R: void functions returning no value, enumerated data types to assign stepped values to variables, data passing between structures by assignment.

The greatly expanded libraries (325 functions!) enable the file sharing and record locking provisions of DOS 3.1, provide a full complement of transcendentals, and a host of utilities to mimic the UNIX and XENIX™ environments.

Lattice 3.0 defaults to the ANSI proposed standard when you need strict adherence, but command line options restore leniency. And it adopts ANSI checking of external function arguments by data type to kill bug swarms when modules join up at link time.

Lattice now delivers smaller .EXE files, boasts very fast link times and a more efficient aliasing algorithm. New options generate code to use 80186 and 80286 features; 8087 of course sensed and utilized. Lattice has enjoyed pre-eminence so long that developers have created far more snap-on tools for Lattice C than any other compiler. William Hunt's *PC Tech Journal* review of 12 compilers awarded Lattice the only "very good" rating for add-on library availability.

Ask for:	List:	PC Brand:
S0100	$500	$299

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BETTER BASIC

Convert Microsoft BASIC. Structured, Compilable.

Combines the familiarity of BASIC with the best features of C, Pascal, and Modula 2, yet BetterBASIC is 100% compatible with Microsoft's GW™ BASIC and IBM BASICA including graphics, sound, and assembly language calls. So load your old programs and RUN. SAVE and they are converted automatically to BetterBASIC!

It's big. Needs 192k; programs can go to the PC's full 640k. It's comfy: Behaves like M'soft BASIC at the interactive level, with a full-screen editor, direct statement execution, and always poised to RUN. It's fast: Each statement checked and compiled once, not every time encountered. Sieve runs *6 times faster* than with M'soft.

C-like structures house file records so goodbye to FIELD, MKI$, CVD, LSET, etc. Named "procedures" replace GOSUBs to linenumbers. Lots more features: built-in linker for compiled modules; trace; debugging breakpoints; cross-reference command; 32k strings; DOS and BIOS calls and interrupts; recursion. Run-time module stores object code for redistribution.

Ask for::	List:	Us:
S1200 BetterBASIC	$195	$165
S1201 Run-time Module	$250	$225
S1202 8087 Interface	$ 99	$ 85
S1205 Btrieve Interface	$ 99	$ 85

GSS GRAPHICS SYSTEM

ANSI CGI STANDARD!

PRICES CUT!

Leave the Device Driving to GSS

GSS™ has reconfigured two components of its comprehensive graphics tools to conform with the ANSI Computer Graphics Interface (CGI) standard.

At the heart of the system is the Development Toolkit which contains all language interfaces and device drivers for keyboards, mice, joysticks, tablets, printers, plotters, cameras, and more. Drivers house management of vector graphics (plotters) and bitmaps used by raster input devices (scanners) to insulate the application program from concern for device idiosyncracy. No one else has implemented CGI that way. It means your programming remains generic; just switch drivers and the same program will drive a different device.

GSS Kernel™ conforms to level 2b of ANSI's Graphical Kernel System (GKS) and contains all its needed drivers and language bindings. Kernel has macro level tools to draw and color an object, store the sequential instructions, and recreate the object on its own, as well as segment it, transform it, etc. So powerful, a single command may represent several score lower level statements.

Plotting has the equivalent GKS tools for graph and chart generation and their captioning: hand it apples and oranges, say "pie", and it bakes the numbers into a digestible display for screen or plotters.

Kernel and Plotting have tools to convert images they create to ANSI Computer Graphics Metafiles (CGMs), a tokenized standard for storing every form of graphic image as data. The Metafile Interpreter reads the contents of a CGM and interprets it with full CGI capability for re-creation on various devices.

Quality software? IBM thinks so. They sell the GSS series under their own label.

Unit royalties and annual fees have been instituted for redistribution. Needs 256k.

Ask for:	List:	PC Brand:
GS010 CGI Dvlpmt Toolkit	$495	$375
GS020 Kernel System	$495	$375
GS025 Kernel for IBM RT	$795	$645
GS030 Plotting System	$495	$375
GS040 Metafile Interpreter	$295	$235

BTRIEVE

ASK ABOUT XTRIEVE & RTRIEVE

Queen B-tree File Manager Abdicates Royalties

There's no longer a tithe to incorporate Btrieve™ in applications, a welcome proclamation if royalties would ruin your profit margins. Btrieve takes complete charge of all file creation, indexing, reading, writing, insertion, deletion, space recapture, forward and backward searching. It builds function call "commands" right into the language you use: interfaces to C, Pascal, BASIC, and COBOL, with sample programs in all four, come with each copy.

Btrieve has mainframe specifications! Its balanced-tree indexing scheme finds any key in a million in four or less accesses. Files may have up to 24 indexes; fixed record length to 4090 characters; indexes up to 255 characters; files of 4 billion bytes. Can even extend a file across two drives — even two hard disks!

Version 4.x speeds DOS interaction for large multiply-keyed files; enables variable length records of virtually any length; verifies accuracy (optionally) with read after write, useful in gritty environments; offers password and data encryption.

There's also Xtrieve, for Btrieve file inquiry and data manipulation, and Rtrieve for report writing. All three in versions for any network that supports the MS-DOS 3.1 file sharing function.

Ask for:	List:	PC Brand:
S0650	$250	$195
S0652 Network Version	$595	$465

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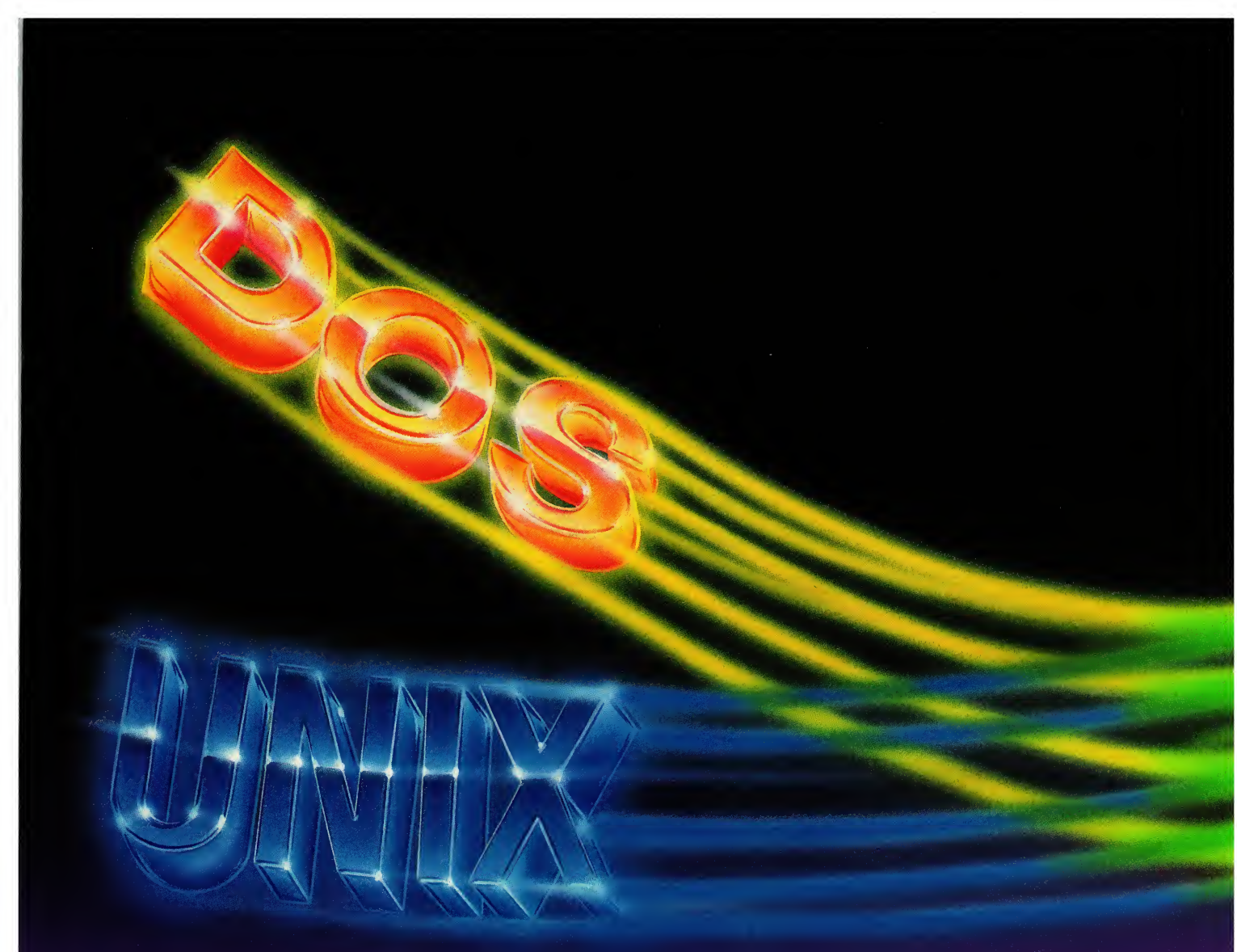


Binary Transfer

RONALD FLORENCE

An XMODEM module for a UNIX-based system allows transmission of data, including non-ASCII files, between a DOS and a UNIX system.

The rapid proliferation of microcomputers has created a PC culture that, to a great extent, has trouble communicating with the older mainframe/minicomputer culture. Many mainframes and some minicomputers have hardware limitations that restrict asynchronous communications to de facto six- or seven-bit words and a limited set of control characters (line feed, carriage return, backspace). By contrast, most PCs make no limitation on the use of all eight bits of each character. Each culture has evolved its own data transmission protocols, and only a few of these protocols have the capability of translating between the two.

In the world of PCs, the XMODEM protocol has become the lingua franca of machine-to-machine transfers. Although many businesses use proprietary transfers such as Microstuf Crosstalk or Hayes Smartcom, which, by using long data blocks of 512 bytes, are efficient and fast, these programs require both the receiver and sender to be set up for the same protocol. For bulletin boards, CompuServe, and direct machine-to-machine links, XMODEM is the norm. Most PC communications programs, whether commercial or public domain, include it. The sidebar "The XMODEM Process," on page 147, briefly explains the protocol. (See also "Screenspeak," Augie Hansen, November 1984, p. 151, for a discussion of Smartcom and XMODEM, and "High-tech Mimicry," Augie Hansen, September 1984, p. 46, for a comparison of 10 communications packages, including Crosstalk.)

Among mainframes and minicomputers, however, XMODEM is virtually unknown, mainly because it uses all eight bits of each transmitted byte. To transfer binary data, the larger machines must use a protocol that includes a quoting mechanism to send eight-bit data in seven bits. The quoting mechanism prefixes a character with a quote character (# or &) to indicate that the high-order bit of the following character is set. The extra characters, including the additional quoting characters (which must be sent to indicate that a # in the data stream is only a # and not a quoting character), exact a high toll in terms of overhead.

Kermit, the protocol developed at Columbia University to bridge mainframe-to-microcomputer transfers, is

ILLUSTRATION • J. A. LAPINSKI

flexible, versatile, and reliable, with the capability of translating file-naming conventions and establishing a packet-exchange handshake between machines. (See "Kermit," Augie Hansen, January 1985, p. 110). Kermit includes quoting mechanisms for machines that cannot send or receive eight-bit data. The price of this flexibility, however, is speed: because Kermit transfers data in short packets of approximately 90 characters, it is somewhat slower than XMODEM. In *any* protocol transfer, each packet includes the overhead of synchronization characters, packet numbers, checksums or CRCs (cyclic redundancy checks), and the wait for the acknowledgment from the remote machine. Hence, the shorter the packets, the greater the overhead. Kermit is available in some PC communications programs, but it is not used extensively.

For many PC users, the most common interaction with minicomputers takes place with systems running UNIX. Frequently, the only file-transfer protocol available between the machines is an ASCII dump. A **stty** command on the UNIX machine can be used to map the line endings from the DOS CR-LF combination to the UNIX NL, or vice versa. To dump a file onto the UNIX system, the remote user enters the command **cat > filename** on the UNIX system. Anything sent from the remote terminal up to an EOF (Ctrl-D for most UNIX systems) is put into **filename** on the UNIX system. To dump an ASCII file from the UNIX machine to a PC logged on as a terminal, the user opens the capture file on the local machine and enters **cat filename** on the UNIX machine. These simple procedures can be enhanced using UNIX commands such as **mesg n**, which prevents other users from writing to the terminal screen during the transfer, or **echo**, which signals the end of the transfer.

These ASCII dumps are efficient, but they offer no error-checking (an increasingly important feature as long-distance carriers compete by cutting line quality in conjunction with costs). Even if the connection is noise-free, a seven-bit ASCII dump cannot transfer binary files. For those who use UNIX machines with cross-compilers as software development systems for DOS, neither object files nor executable programs can be transferred between the UNIX system and a DOS machine using these ASCII dump procedures. For example, a developer using his DOS machine at home with a modem as a terminal on a remote UNIX machine, could not download the executable DOS version of his program from the UNIX machine without an eight-bit protocol.

In addition, UNIX-based machines are limited in their ability to call to other machines by the absence of the XMODEM protocol. The typical university or engineering super microcomputer or minicomputer, running some version of UNIX, communicates with other UNIX machines using **cu** (call up) for interactive communications, or **uucp** (UNIX-to-UNIX communications program) for unattended file transfers. Both programs rely on a streamlined ASCII dump to transfer text or source files. For binary transfers, most UNIX systems use a version of Kermit. These programs work well for communications between UNIX systems, but **cu** and C-Kermit (another such program) lack support for the file-transfer protocols used by most DOS bulletin boards and some large database systems.

UNIX systems have no problem with eight-bit data, as long as the **stty** or **ioctl( )** functions that condition the line are set for eight-bit characters. Thus, XMODEM should be adaptable for use on a UNIX system, so that a caller with a PC can log on using a DOS terminal program, such as Crosstalk or Headlands' PC-TALK, and make error-checked file transfers to and from the UNIX system using XMODEM. (See "PC-TALK: Communications Control," Will Fastie, September/October 1983, p. 162.) For UNIX users with source licenses, the UNIX communications program also can be modified to include XMODEM.

UNIX systems can handle eight-bit data as long as the stty or ioctl( ) functions that condition the line are set for eight-bit characters.

The code in listing 1 (XMODEM.C) is a module, written in C, that will handle the XMODEM transmission or receipt of files to and from a UNIX system, using either checksum or CRC error checking. (See "CRC Calculation," W. David Schwaderer, April 1985, p. 118.) The code includes an option for the transfer of text files between a DOS machine and a UNIX machine; if the text option is invoked, the transfers will make the conversions between DOS CR-LF line-endings and UNIX NLs.

XR AND XT

Compiled with the code in listing 2 (XR.C), the **xmodem** module produces a stand-alone remote XMODEM program for UNIX systems. The compiled program **xr** is linked with another file called **xt**. (A file link in UNIX creates two separate names for the same file.) XR.C parses to determine which name has been used to invoke the program: **xr** is invoked to receive files, **xt** to send files. The executable file(s) should be in a directory on the UNIX system that is on the default path of most users, such as **/usr/bin** or **/usr/lbin**. The invocation format for the two is the same except for the file name, either:

xr [–ct] [–d errfile] filename

or

xt [–ct] [–d errfile] filename

The **–c** option provides CRC error checking instead of the default checksum; **–t** provides text file line-end conversions; and **–d** provides verbose debugging information in a user-specified file on the UNIX system.

To send a file to the UNIX system from the PC using XMODEM, the user would enter the command

xr [options] filename

on the UNIX system. The **xr** program checks to see if it can write the file on the UNIX system or announces that it cannot (if, for example, the user has given a path that has no write permission). If the file already exists, instead of overwriting the file, **xr** will create **filename~**. This is a crude sort of collision-protection scheme, which fails with longer (14-character) file names.

The user then begins the XMODEM file transmission on the PC terminal program. To cancel the transfer, the PC sends a Ctrl-X, (the CAN character used by XMODEM), which is sent automatically by most XMODEM programs when a transfer is aborted.

To send a file from the UNIX system to the PC, the user would enter

xt [options] filename

on the UNIX system. If the file exists, and can be read, **xt** announces that it is ready to begin the transfer and give the size in blocks of 128 bytes. Then, the user would invoke the XMODEM receive procedure on the PC terminal program. The **xt** program automatically adjusts to the error-checking method specified by the receiver program. Again, Ctrl-X aborts the transfer.

If the **–t** option is used to send text files or source code between a DOS

THE XMODEM PROCESS

The XMODEM protocol is prevalent as a method of file transfer in the PC environment. It was originally developed by Ward Christensen for use on machines that were running CP/M operating systems. The protocol's ability to send binary files with some error checking over less-than-perfect telephone lines is the reason for its widespread adoption.

An XMODEM protocol file transfer between two computers is shown schematically in figure 1. The vertical bars show relative time proceeding downward. Various "messages" are depicted as arrows pointing in the direction of the receiver of the message. For the purposes of this discussion, it is assumed that the computer on the left is sending a file to the computer on the right.

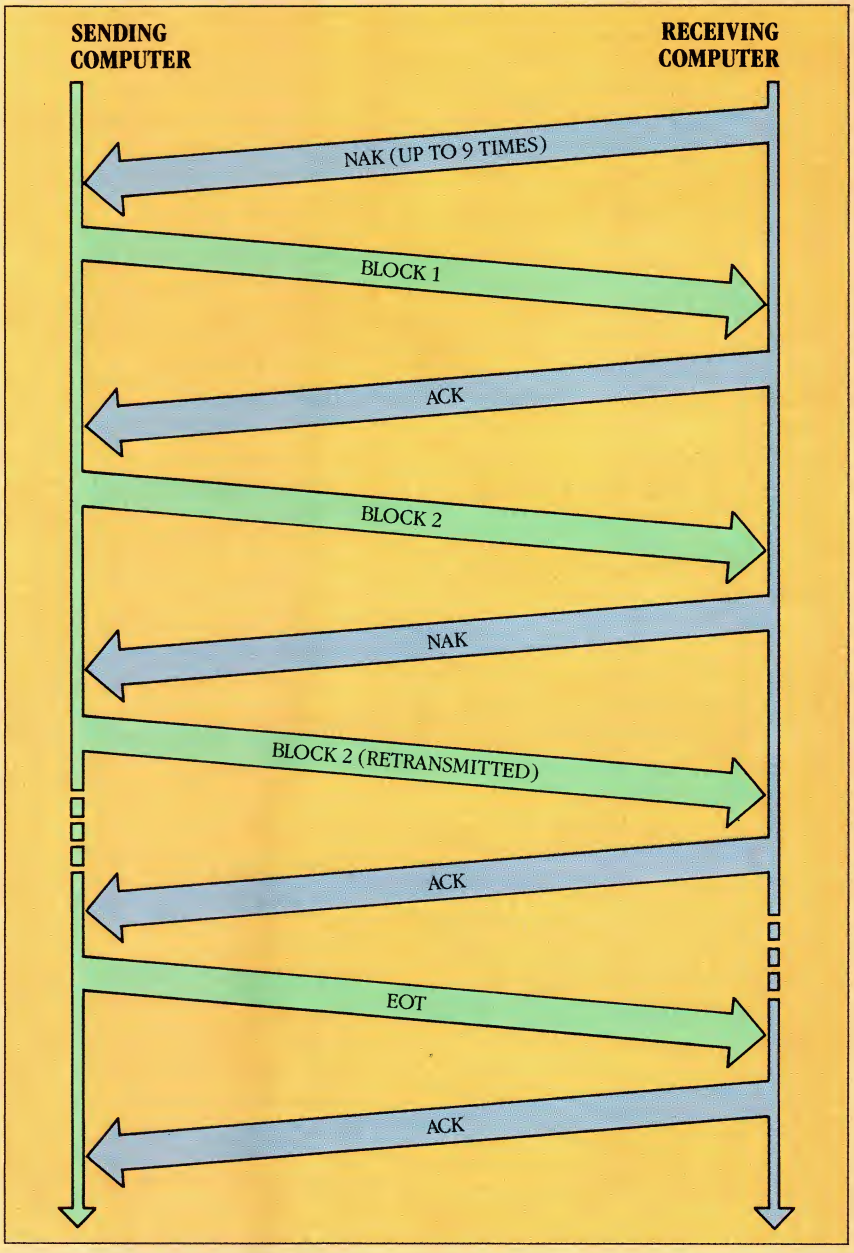
The transfer is initiated when the receiving computer sends an NAK (negative acknowledgment) message to the sending computer, indicating that it is ready to synchronize and receive a file. It will send NAK characters at 10-second intervals until the sender begins transmitting the file or until nine NAKs have been sent, indicating that the sender is not responding.

Assuming that the sender synchronizes, the first block is transmitted. A block, depicted in figure 2, consists of an SOH (start of header) character, a block number (sequential up to 254) expressed as an ASCII character followed by the character equivalent of the one's complement of the block number, then 128 bytes of data, padded if necessary to fill the block, and a checksum value derived from the transmitted data.

The checksum is calculated by adding the ASCII values of the characters in the 128-byte block, then ANDing the results with 255. If the receiver calculates the same checksum value for the received data, an ACK (acknowledgment) is returned to the sender, indicating success. Failure is indicated by an NAK, which would result in a retransmission of the block until it is received correctly or until nine retries have been made. When the sender has no more data to send to the receiver, it transmits an EOT (end of transmission) character and awaits an ACK, which terminates the transfer.

—Augie Hansen

FIGURE 1: *A File Transfer via XMODEM*



The receiving computer (right) will send NAK (negative acknowledgment) characters at 10-second intervals until the sender begins transmitting the file or until nine NAKs have been sent, thus indicating the sender is not responding.

FIGURE 2: *XMODEM Block Description*

Each block of data that is to be transmitted must contain a full 128 bytes. If the block is shorter than 128 bytes, it must be padded to the full length.

system and a UNIX system, the file lengths on the UNIX machine will be shorter than the file lengths on the DOS machine. This is a result of the line-end conversions that take place.

USING XMODEM WITH CU

For users with UNIX (or XENIX) source licenses, the **xmodem** module can be compiled with a modified version of **cu** to provide XMODEM in the principal UNIX (or XENIX) communications program. The modified **cu** can be used to call a bulletin board or another remote computer that uses XMODEM for error-checked file transfers to and from the UNIX (or XENIX) system.

The **cu** program, like many such programs in UNIX, uses **fork( )** to establish two parallel processes, one to receive incoming data on the open communications line, the other to examine everything typed at the keyboard, parsing and interpreting commands, and sending the other characters out over the open line. To use **xmodem**, **cu** or another UNIX communications program requires the following code:

- A command-parsing mechanism that recognizes the options (CRC instead of the default checksum error-checking, NL to CR-LF line-end conversion for text files, debugging mode).
- Code to kill the receive fork of the communications program and recondition the open communications line to no parity, no stripping of characters to seven bits, no XON/XOFF protocol, and eight-bit characters.
- A new fork to invoke **xget( )** or **xput( )** with the file name and the appropriate options.
- A **longjmp( )** to restart the receive process of the terminal program (and recondition the communications line back to its original settings) when the file transfer is complete.

The options are passed by setting the appropriate bits in the integer parameter options. The file pointer to the open file is passed in the parameter **fp**. The external file **rlfd** is the open communications line in **cu**.

The **–DCU** compile option for XMODEM.C sets up the SIGINT signal (the DEL key) to cancel file transfers, and includes code to place a period (.) on the screen for each successful packet transfer, or a percentage symbol (%) for each unsuccessful transmission. If the debug option is invoked, the screen prints verbose messages about failed packets. The **xmodem** module could be incorporated into another communications program, such as C-Kermit, with minimal modifications.

XMODEM.C

The code in XMODEM.C is straightforward. The NOREAD( ) and TX( ) macros and the **err( )** function are used to simplify the code. Static **chars**, rather than **define** statements, are used for SOH (start of header), NAK (negative acknowledgement), ACK (acknowledgement), EOT (end of transmission), CAN (cancel), and **crcinit**, because the UNIX **write( )** call needs the address of the character to be sent. A loop in **xget( )** and the **fillbuf( )** function manage the conversion to and from CR-LF line endings if the text option has been specified. To allow the sender time to set up the XMODEM transmission before the synchronized characters are sent, a **sleep(10)** call is used in **xget( )**. **Sleep( )** is a library function that suspends execution for an interval.

Few constraints are placed on the code for the XMODEM transmission functions; however, the XMODEM receiver must be able to keep up with the sender's transmissions. At 1,200 or even 2,400 bps (bits per second), little danger exists of losing characters; higher transmission speeds place demands on the code. To be certain that characters are not lost, the data bytes are not sent through the checksum or CRC generator until the entire data block is received. Some XMODEM programs available on bulletin boards update screen displays during packet transfers, with the result that they cannot run above 1,200 bps without losing characters.

The bit-level operators in C make the CRC generator a relatively simple function. The bytes that are to be added to the CRC are fed into the generator one bit at a time, high bit first. The bit is shifted into a 16-bit CRC accumulator, and, if the bit shifted out of the CRC accumulator is a 1, an exclusive-or is performed on the CRC accumulator using the bit pattern 1021H. The process repeats for all eight bits of the input character. To make the CRC come out correctly for XMODEM, two zeros must be sent through the generator after the data bytes. These zeros take the place of the CRC bytes in the packet.

The UNIX alarm signal (SIGALRM) is used to signal a time-out on the receive function, by interrupting the system call **read( )** in function **rchar( )**, which returns a –1 to indicate an error. Any other interruption to the **read( )** also causes the read to signal a time-out and the program to recycle and request the block again. Programs that make high-priority system calls to the kernel, such as some windowing programs, interrupt **read( )**, but XMODEM is suffi-

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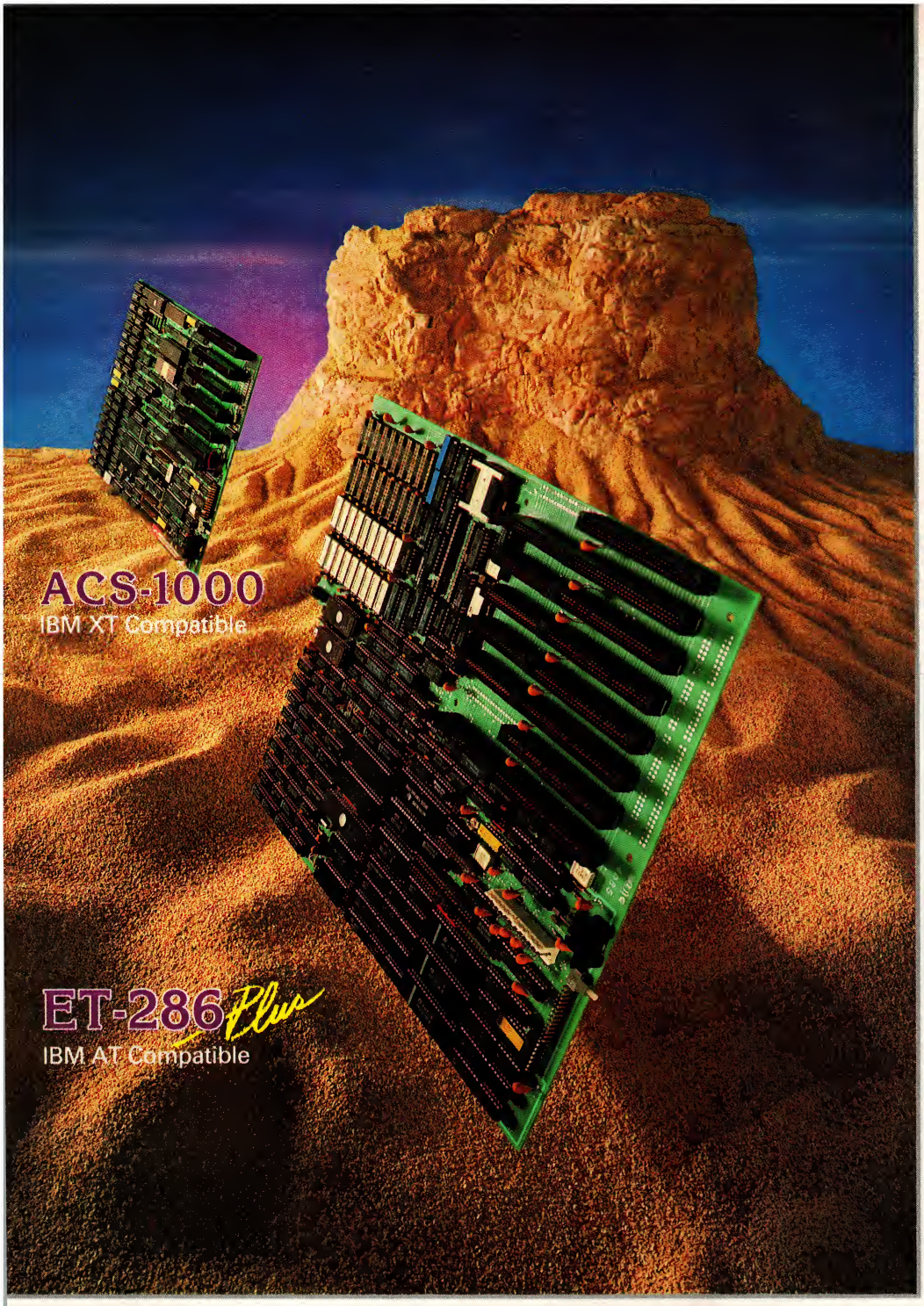

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ciently robust to immediately resend the packet. Function **cksend( )** uses **rchar( )** to clear the communications line before an ACK, NAK, or CAN is sent back to the XMODEM sender.

XR.C

The code for **xr** and **xt** uses stock UNIX C library functions to parse the command line and to set the communications line for the XMODEM transmission. The initialization for the character **trans???** determines whether the program has been invoked as **xr** or **xt**.

The **termio** structures **new** and **old** are used to set and reset the line, and the structure **stbuf** is used to get the file size for files that are to be transmitted. The SIGINT and SIGQUIT traps prevent an accidental press of DEL or Ctrl-\ from aborting the transmission, and the SIGHUP trap ensures the program's cleanup in the event the telephone line is disconnected accidentally.

The XMODEM protocol is quick and highly accurate for attended file transfers. The code in these modules requires that both sender and receiver machines have the name of the file entered. Some newer versions of XMODEM include a batch-level protocol that sends file-name headers before each file. Code written to incorporate the batch protocol for transfers between UNIX and DOS machines would need to address the difference in the file-naming conventions of the two systems: DOS file names are limited to an eight-character name with a three-character suffix, use a backslash instead of a slash as the separator in path names (except DOS 2.x, which also allows the backslash), and DOS translates file names to uppercase. UNIX permits file names in any combination up to 14 characters; the slash is used as a directory separator; and file names, like commands, are case-sensitive, thus, MYFILE.DOS, myfile.dos, Myfile.dos, and mYfile.dos are all different file names. File names sent from a DOS system are acceptable to a UNIX system, but if they are not mapped to lowercase, they end up at the head of sorted directory listings. (Most UNIX file names are lowercase.) Many UNIX file names, because of their length, format, or the inclusion of characters outside the allowed DOS set, would not be acceptable to DOS machines until they were translated to the format required by DOS.

In addition to its uses in transfers between UNIX and DOS machines, XMODEM also can be a time-saver in transfers between UNIX systems. Sending files that have been compressed with **pack** and bundled with **tar** is substantially faster than the ASCII dumps of **cu** and **uucp**. It is particularly convenient to be able to shift from ASCII to binary transfers while using **cu**, instead of having to do some transfers with **cu** and others with C-Kermit.

The XMODEM protocol is a useful bridge between DOS and UNIX. Its transfers are fast, simple, and reliable; moreover, it is sometimes the only means of uploading or downloading binary files or of effecting error-checked transfers of text or source code files between the two systems when a UNIX machine is used to develop DOS programs or when a UNIX machine serves as a terminal for DOS bulletin boards. Indeed, this article and the accompanying code were transmitted from a XENIX system to a DOS machine at *PC Tech Journal* using XMODEM for XENIX and UNIX.

Ronald Florence is a novelist and historian and a devotee of the UNIX operating system. His most recent published work is The Optimum Sailboat *(Harper & Row, 1986).*

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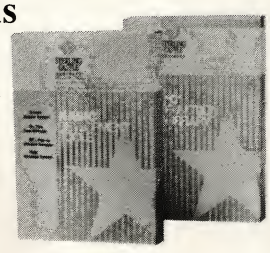

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LISTING 1: XMODEM.C

```
/* XMODEM.C copyright 1986 Maple Lawn Farm, Inc.
 * exit: 0 if successful, -1 for failure, compile with mlfcu.c:
 *      cc -i -O -s -DCU mlfcu.c XMODEM.C -o cu or with XR.C:
 *      cc -i -O -s XR.C XMODEM.C -o xr, ln xr xt */

#include <signal.h>
#include <stdio.h>

#ifdef CU

extern int      rlfd;           /* the open line in cu */
#define WFD     rlfd
#define RFD     rlfd
#define errf    stderr

#else

extern  FILE    *errf;          /* error file for remote */
#define WFD     1               /* stdout */
#define RFD     0               /* stdin */

#endif

#define BSIZE           128
#define DEBUG           01
#define LF              02
#define CRC             04
#define NOREAD(x, c)    (rchar(x, &c) == -1)
#define TX(c)           write(WFD, &c, 1)
#define ever            (;;)

static  char    soh = 0x01,
                eot = 0x04,
                ack = 0x06,
                nak = 0x15,
                can = 0x18,
                crcinit = 'C',
                cksum;

static  int     debug,
                crc;

int     kleenex(),
        onalarm();

unsigned        crcsum;

xget(fp, opts)
FILE    *fp;
int     opts;
{
        char    buf[BSIZE],
                b = 1,
                inch,
                crchi;
        int     iput = BSIZE;
        register        i;

        debug = (opts & DEBUG);
        crc = (opts & CRC);
        signal(SIGALRM, onalarm);
#ifdef CU
        signal(SIGINT, kleenex);
#else
        sleep(10);
#endif
        (crc) ? TX(crcinit) : TX(nak);
        for ever {
           if NOREAD(10, inch) {
                err("Timeout during SOH");
                cksend(crc ? crcinit : nak) ;
                continue;
           }
           if (inch == eot)
                break;
           if (inch == can) {
                err("CAN block %u", b);
                kleenex(-1);
           }
```

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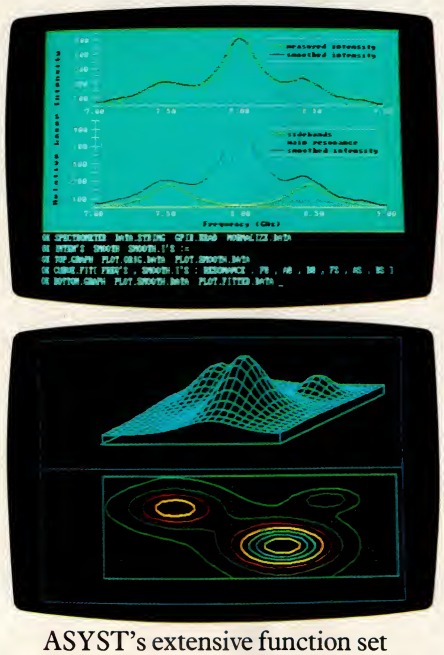

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```
        if (inch != soh) {
            err("Bad $OH block %u: %#x", b, (inch & 0xff));
            cksend(nak);
            continue;
        }
        if NOREAD(2, inch) {
            err("Timeout block %u during blocknum", b);
            cksend(nak);
            continue;
        }
        if ((inch & 0xff) != b) {
            err("Expected blocknum %u, got %u", b, (inch & 0xff));
            cksend(nak);
            continue;
        }
        if NOREAD(2, inch) {
            err("Timeout block %u during ~blocknum", b);
            cksend(nak);
            continue;
        }
        if ((inch & 0xff) != (~b & 0xff)) {
            err("Expected ~blocknum %u, got %u",
                    (~b & 0xff), (inch & 0xff));
            cksend(nak);
            continue;
        }
/* Read in 128 byte block without taking time for checksums or crc. */
        for (i = 0; i < BSIZE; i++)
            if NOREAD(2, buf[i])
                break;
        if (i < BSIZE) {
            err("Timeout data recv, char #%d", i);
            cksend(nak);
            continue;
        }
        if (crc) {
            if NOREAD(2, crchi) {
                err("Timeout crc hibyte");
                cksend(nak);
                continue;
            }
            crchi &= 0xff;
        }
        else if NOREAD(2, inch) {
            err("Timeout %s", (crc) ? "crc lobyte" : "checksum");
            cksend(nak);
            continue;
        }
/* Now, when we have the whole packet, do the checksum or crc. */
        for (cksum = 0, crcsum = 0, i = 0; i < BSIZE; i++)
            upsum(buf[i]);
        if (crc) {
            upsum(0);       /* needed for crcsum */
            upsum(0);
            if ((inch & 0xff) + (crchi << 8) != crcsum) {
                err("Expected crc %u, got %u",
                        crcsum, (inch & 0xff) + (crchi << 8));
                cksend(nak);
                continue;
            }
        }
        else {
            cksum %= 256;
            if (cksum != (inch & 0xff)) {
                err("Expected checksum %u, got %u",
                        cksum, (inch & 0xff));
                cksend(nak);
                continue;
            }
        }
        TX(ack);
#ifdef CU
        putc('.', stderr);
#endif
        if (opts & LF)
            for (i=0, iput=0; i < BSIZE; i++) {
                if (buf[i] == 0x1a)  /* old ms-dos eof */
                    break;
                if (buf[i] != '\r')
                    buf[iput++] = buf[i];
            }
```

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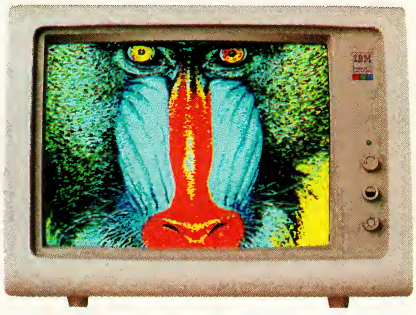

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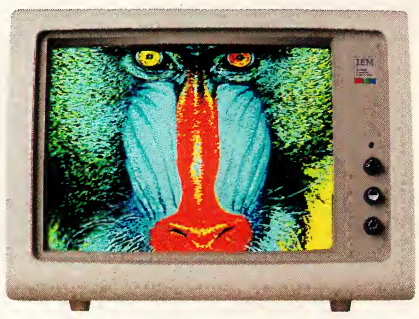

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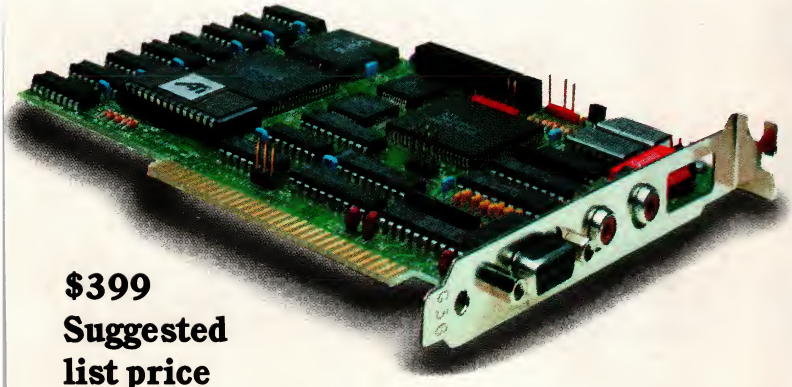

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```
            fwrite(buf, iput, 1, fp);
            b++;
            b %= 256;
        }
        TX(ack);
        kleenex(0);
}

xput(fp, opts)
FILE    *fp;
int     opts;
{
    register    i;
    char    buf[BSIZE],
            b = 1,
            cb,
            crclo,
            inch;
    int     cread;

#ifdef CU
    signal(SIGINT, kleenex);
#endif
    signal(SIGALRM, onalarm);
    debug = (opts & DEBUG);
    rchar(60, &cb);
    if (cb == crcinit)
            crc = 1;
    else if (cb == nak)
            crc = 0;
    else {
            err("No startup %s", (crc) ? "'C'" : "NAK");
            kleenex(-1);
    }
    cread = fillbuf(fp, buf, (opts & LF));
    while (cread) {
            for (i = cread; i < BSIZE; i++)
                    buf[i] = 0;
            TX(soh);
            TX(b);
    cb = (~b & 0xff);
    TX(cb);
    write(WFD, buf, BSIZE);
    for (cksum = 0, crcsum = 0, i = 0; i < BSIZE; i++)
            upsum (buf[i]);
    if (crc) {
            upsum(0);       /* needed for crcsum */
            upsum(0);
            crclo = crcsum;
            cb = (crcsum >> 8);
            TX(cb);
            TX(crclo);
            }
            else {
                    cksum %= 256;
                    TX(cksum);
            }
            if NOREAD(15, inch) {
                    err("Timeout after block %u", b);
                    continue;
            }
            if (inch == can) {
                    err("CAN after block %u", b);
                    kleenex(-1);
            }
            if (inch != ack) {
                    err("Non-ACK after block %u: %#x", b, inch);
                    continue;
            }
#ifdef CU
            putc('.', stderr);
#else
            if (debug)
                    fprintf(errf, "Validated block %u\n", b);
#endif
            cread = fillbuf(fp, buf, (opts & LF));
            b++;
            b %= 256;
        }
        for ever {
            TX(eot);
            if NOREAD(15, inch) {
                    err("Timeout during EOT");
                    continue;
            }
            if (inch == can) {
                    err("CAN during EOT");
                    kleenex(-1);
            }
            if (inch != ack) {
                    err("Non-ACK during EOT: %#x", inch);
                    continue;
            }
            break;
        }
        kleenex(0);
}

fillbuf(fp, buf, lf)
FILE *fp;
char *buf;
int lf;
{
        int     i = 0, c;
        static  int     cr_held;
        if (cr_held) {
                buf[i] = '\n';
                i++;
                cr_held--;
        }
        for (; i < BSIZE; i++) {
                if ((c = getc(fp)) == EOF)
                        break;
                if (c == '\n' && lf) {
                        buf[i] = '\r';
                        if (i == 127) {
                                cr_held++;
                                return BSIZE;
                                }
                                buf[i+1] = '\n';
                                i++;
                        }
                else
                        buf[i] = c;
        }
        return i;
}

upsum(c)
char    c;
{
        register  unsigned  shift;
        register  unsigned  flag;

        if (crc)
                for (shift = 0x80; shift; shift >>= 1)  {
                        flag = (crcsum & 0x8000);
                        crcsum <<= 1;
                        crcsum |= ((shift & c) ? 1 : 0);
                        if (flag)
                                crcsum ^= 0x1021;
                }
        else
                cksum += c;
}

/* Timeout in rchar() works by deliberately interrupting the read()
 * system call.  errno=EINTR, so no reason for a perror() autopsy. */
rchar(timeout, cp)
unsigned timeout;
char *cp;
{
    int     c;

    alarm(timeout);
    if ((c = read(RFD, cp, 1)) == -1)
            return -1;
    alarm(0);
    return c;
}
```

```
onalarm()
{
   signal(SIGALRM, onalarm);
}

kleenex(sig)
int sig;
{
#ifdef CU
   if (sig > 0)
        cksend(can);
   else
        fprintf(stderr, "\r\nFile transfer %s.",
             (sig) ? "cancelled" : "complete");
   fprintf(stderr, "\r\n");
#else
   printf("File transfer %s.\r\n", (sig) ? "cancelled" : "complete");
   resetline();
#endif
   exit(sig);
}

cksend(ch)
char ch;
{
   int j;
   char cp;

   do {
        j = rchar(2, &cp);
   } while (j != -1);
   TX(ch);
}

/* VARARGS1 */
err(s, i, j)
char    *s;
int     i, j;
{
     if (debug) {
          fprintf(errf, s, i, j);
#ifndef CU
          fprintf(errf, "\n");
     }
#else
          fprintf(errf, "\r\n");
     }
     else
          putc('%', stderr);
#endif
}
```

LISTING 2: XR.C

```
/* XR.C - remote xmodem functions for xenix/unix
 * copyright 1986 Maple Lawn Farm, Inc.
 * usage: xr|xt [-ct] [-d errfile] file
 * -c   crc (instead of checksum), -t   text mode (CR-NL <-> NL)
 * compile:     cc -i -O -s XR.C XMODEM.C -o xr
 *              ln xr xt
 * To avoid overwriting existing files, received file with same name
 * as an existing file is stored as fname~. */

#include <signal.h>
#include <stdio.h>
#include <fcntl.h>
#include <sys/ioctl.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <termio.h>

#define DEBUG       01
#define LF          02
#define CRC         04
#define BSIZE       128
#define errx(m,f)   printf("%s: ", pname), \
                    printf(m, f), \
                    printf("\n"), \
                    exit(1)

FILE    *errf;

struct  termio  old,
                new;
hangup()
{
        resetline();
        exit(1);
}

main(ac, av)
int     ac;
char    **av;
{
        char    *pname,
                trans = (av[0][strlen(av[0]) -1] == 't'),
                *fname;
        int     c, opts = 0;
        struct  stat    stbuf;
        extern  int     optind;
        extern  char    *optarg;
        FILE    *fp;

        pname = *av;
        while ((c = getopt(ac, av, "ctd:?")) != EOF)
          switch (c)  {
          case 't' :
                opts |= LF;
                break;
          case 'c' :
                opts |= CRC;
                break;
          case 'd' :
                opts |= DEBUG;
                if (!(errf = fopen(optarg, "w")))
                    errx("can't open %s", optarg);
                setbuf(errf, NULL);
                break;
          case '?' :
                printf("usage: %s [-ct] [-d errfile] file\n", pname);
                exit(1);
          }
        if (ac == 1 || ac == optind)
          errx("need file name", NULL);
        fname = av[optind];
        if (trans && !(fp = fopen(fname, "r")))
          errx("can't open %s", fname);
        if (!trans) {
          if (!access(fname, 0))
                strcat(fname, "~");
            if (!(fp = fopen(fname, "w")))
                errx("can't write %s", fname);
        }

        printf("Ready to %s %s\n", (trans) ? "send":"receive", fname);
        if (trans) {
          stat(fname, &stbuf);
          printf("%d blocks (128 bytes/block)\n",
                    stbuf.st_size/BSIZE+1);
        }
        printf("Ctrl-X to abort transfer\n");

        signal(SIGINT, SIG_IGN);
        signal(SIGQUIT, SIG_IGN);
        signal(SIGHUP, hangup);

        ioctl(1, TCGETA, &old);
        ioctl(1, TCGETA, &new);
        fflush(stdin);
        new.c_iflag = IGNBRK|IGNPAR;
        new.c_oflag = 0;
        new.c_lflag = 0;
        new.c_cc[4] = 1;
        new.c_cflag &= ~PARENB;
        new.c_cflag |= CS8;
        ioctl(1, TCSETAW, &new);

        (trans) ? xput(fp, opts) : xget(fp, opts);
}
resetline()
{
        ioctl(1, TCSETA, &old);
}
```

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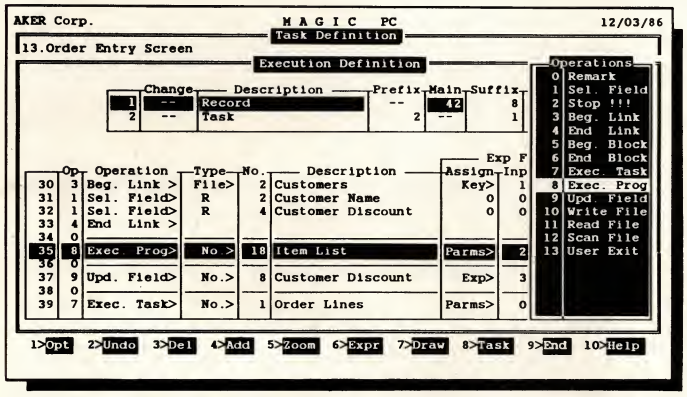
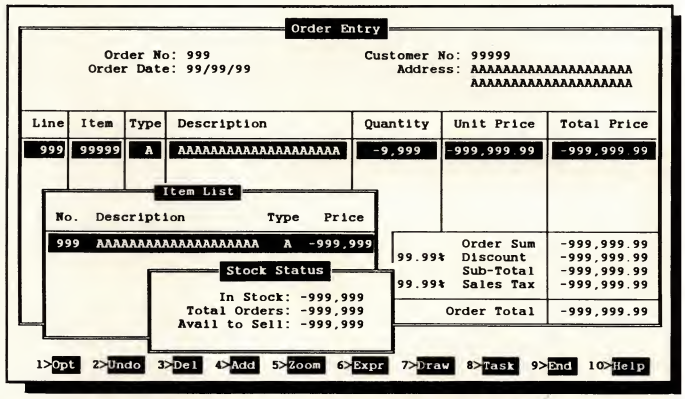


A Magic PC program looks as simple as this. To design an application you quickly fill-in menu-driven decision tables **without having to write a single line of code.** For example, just by highlighting the Execute Program operation on this screen and also highlighting the Item List program in the Program Menu, you tell Magic PC to pop-up the Item List window shown in the adjacent screen, when the end-user hits the Zoom key.



Magic PC gives your end-user the power to harness and retrieve data instantly, **without any commands or syntax** because at runtime you already have built-in options to Add, Delete, Modify, Query and get on-the-spot ad-hoc information simply by highlighting selections from menus. Dats validation, security and error-checking are done automatically for you by Magic PC without programming.

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You're not confined to any particular design sequence as you are with most procedural languages. You can enter and change any Table spontaneously, on the fly, as ideas come to mind and Magic PC automatically maintains the application integrity.

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Min. requirements PC DOS 2.0, IBM PC or 100% compatible with 512K and hard disk

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Procedural Algorithms in Prolog

Strategies are presented for expressing algorithms in Prolog as well as translating algorithms from other languages.

Effective programming is aided by the use of reference books that are complete, and most Prolog textbooks do a thorough job of explaining how to express *information* in Prolog. For example, **bird(tweety).** means "Tweety is a bird," and **fly(X) :- bird(X).** means "X flies if X is a bird."

Much less has been written about how to express *algorithms* in Prolog. Often, a computation is best described not as a set of properties and relations, but as a procedure—perhaps one that already has been developed and debugged in a conventional language.

This article presents strategies for translating algorithms from other languages into Prolog. The examples are in standard Edinburgh Prolog and will run in most implementations without modification. Except where noted, the techniques are equally applicable to Borland's Turbo Prolog, though the sample programs will require changes, such as adding declarations and changing I/O statements. (For a review of three Prolog compilers, see "Prolog Arrives," Michael Covington and Andre Vellino, November 1986, p. 52. See also "Programming in Logic," Michael Covington, December 1985, p. 82 and January 1986, p. 145; and "Programming for AI," Expert Consultant: *Applied AI*, Richard L. Schwartz and Robert E. Shostak, December 1986, p. 191.)

Prolog is often described as a nonprocedural language. It is really a semiprocedural language; a compromise between procedural and nonprocedural programming, it yields some advantages of each. In a truly nonprocedural language, the programmer would specify only a logically rigorous set of conditions the program must fulfill; the computer would then automatically generate an algorithm from them. Such factors as the order in which the conditions were written thus have no effect.

In the interest of efficiency, Prolog contains some procedural elements.

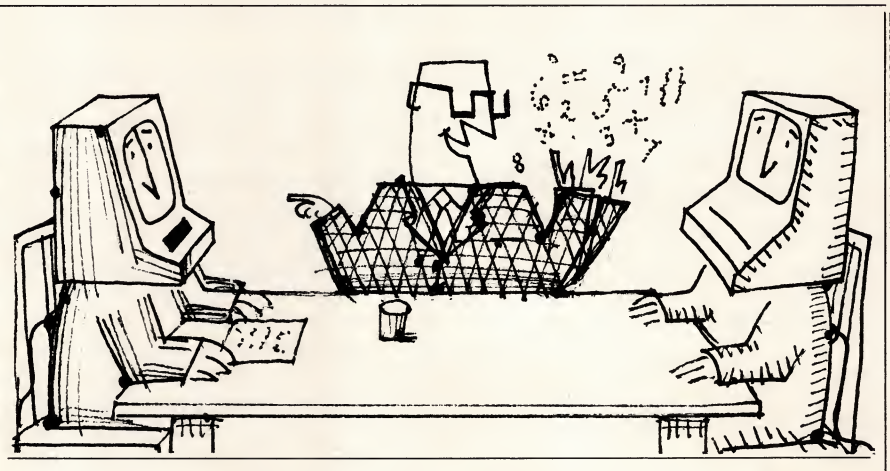

ILLUSTRATION • MACIEK ALBRECHT

The Prolog programmer specifies not only the rules and facts to be used in solving a problem, but also the order in which they are to be attempted. Crucially, the programmer can even specify that some potential paths to a solution should not be tried at all. This makes it possible to carry out computations that would be severely inefficient, or even impossible, in pure Prolog.

The key principle of Prolog is the *procedural interpretation of logic*. Consider the following Prolog rule set:

```
in_north_america(X) :- in_usa(X).
in_usa(X) :- in_georgia(X).
in_georgia(atlanta).
```

This can be interpreted as a set of facts

```
X is in North America if X is in the USA.
X is in the USA if X is in Georgia.
Atlanta is in Georgia.
```

or as a set of procedure definitions

```
To prove that X is in North America,
    prove that X is in the USA.
To prove that X is in the USA,
    prove that X is in Georgia.
To prove that Atlanta is in Georgia,
    do nothing.
```

The unfamiliar task of drawing inferences from data is thereby reduced to the familiar task of calling procedures.

Prolog predicate definitions will be referred to throughout this article as *procedures*, and goals will be referred to as *procedure calls*.

CONDITIONAL EXECUTION

A very important difference between Prolog and other programming languages is that, in general, Prolog procedures have multiple definitions (or clauses), each being applied under different conditions. In Prolog, conditional execution is expressed, not with **if** or **case** statements, but with these alternative definitions of procedures.

Consider for example how the following Pascal procedure might be translated into Prolog:

```
procedure writename(X:integer);
begin
  case X of
    1: write('One');
    2: write('Two');
    3: write('Three')
  end
end;
```

This tanslation could be done by giving **writename** three definitions:

```
writename(1) :- write('One').
writename(2) :- write('Two').
writename(3) :- write('Three').
```

Each definition matches in exactly one of the three cases. A common mistake is to write the clauses as follows:

```
/* poor style */
writename(X) :- X=1, write('One').
writename(X) :- X=2, write('Two').
writename(X) :- X=3, write('Three').
```

This gives correct results but wastes time. Because **X** is a variable, each clause matches every procedure call; so the computer tries each clause, gets part way into it, and then backs out if **X** has the wrong value. It is faster to design the clauses so that only the correct one can be invoked in the first place.

A key to effective programming in Prolog is to make each logical unit into a separate procedure. Each **if** or **case** statement should, in general, become a procedure call. For example, the hypothetical Pascal procedure:

```
procedure a(X:integer);
begin
  b;
  if X=0 then c else d;
  e
end;
```

should go into Prolog as follows:

```
a(X) :- b,
        c_or_d(X),
        e.
c_or_d(0) :- c.
c_or_d(X) :- X<>0, d.
```

This imposes a disciplined organization that is even more rigorous than the structured ("goto-less") programming style that underlies Pascal, C, and Ada.

Consider another version of **writename** that includes a catch-all clause to deal with numbers the names of which are not given:

```
procedure writename(X:integer);
begin
  case X of
    1: write('One');
    2: write('Two');
    3: write('Three')
  else
    write('Out of range')
  end
end;
```

(Standard Pascal does not allow the use of **else** with the **case** statement, but most popular compilers do.) One way to express the same algorithm in Prolog is the following:

```
writename(1) :- write('One').
writename(2) :- write('Two').
writename(3) :- write('Three').
writename(X) :- X<1, write('Out of range').
writename(X) :- X>3, write('Out of range').
```

This gives correct results but lacks conciseness. In order to make sure that only one clause can be executed with each number, the value of **X** was tested in each of the last two clauses. In order to tell the program to print "Out of range" for any number that has not matched any of the first three clauses, the following clauses could be tried, with limited success:

```
/* incorrect */
writename(1)  :- write('One').
writename(2)  :- write('Two').
writename(3)  :- write('Three').
writename(_)  :- write('Out of range').
```

(Recall that the anonymous variable, written as **_**, matches anything.) The problem here is that the goal **writename(1)**, for example, matches both the first clause *and* the last clause. If a subsequent goal fails and causes backtracking through this one, the goal **writename(1)** will have two solutions: one that prints "One" and one that prints "Out of range."

Writename should be *deterministic*—that is, it should give exactly one solution for any given set of parameters and not give alternative solutions upon backtracking. Therefore, if any of the first three clauses succeeds, the computer should be told not to try the last clause. This can be done with the *cut* operator (written as **!**).

The cut operator commits the computer to take a particular (or potential) solution without trying alternatives. Suppose that **b** is defined as follows:

```
b :- c, d, !, e, f.
b :- g, h.
```

and that the current goal is **b**. If the cut is executed on the first clause, then it becomes impossible to look for alternative solutions to **c** and **d** (the goals that precede the cut in the same clause) or to **b** (the goal that invoked the clause containing the cut). It remains possible, of course, to backtrack all the way past **b**—outside the scope of the cut—and look for alternatives to the clause that caused **b** to be invoked.

What is needed to do in the incorrect **writename** expression is to put a cut in each of the first three clauses. This changes their meaning slightly, so that the first clause (for example) says, "If the parameter is 1, then write 'One' and do not try any other clauses."

```
writename(1)  :- !, write('One').
writename(2)  :- !, write('Two').
writename(3)  :- !, write('Three').
writename(_)  :- write('Out of range').
```

Because **write** is deterministic, it does not matter whether the cut is written before or after the call to **write**. Programs are usually more readable, however, if cuts are made early.

GUARANTEEING THE OUTCOME

In order to control the flow of program execution, it is often necessary to guarantee that a goal will succeed regardless of the results of the computation that it performs. Occasionally, it is necessary to guarantee that a goal will always fail.

An easy way to make any procedure succeed is to add a clause to it that succeeds with any parameters and is attempted last:

```
f(X,Y) :- X<Y, !, write('X less than Y').
f(_,_).
```

A call to **f** succeeds with any parameters; it may or may not print its message, but it certainly will not fail and, hence, will not cause backtracking in the procedure that invoked it. Moreover, because of the cut, **f** is deterministic (provided its parameters are already instantiated). The cut prevents the second clause from being used to generate a second solution with parameters that have succeeded with the first clause.

Similarly, a procedure can be guaranteed to fail by adding cut and fail at the end of each of its definitions:

```
g(X,Y) :- X<Y, write('X less than Y'), !, fail.
g(X,Y) :- Y<X, write('Y less than X'), !, fail.
```

Any call to **g** ultimately fails for one of two reasons: either it does not match any of the clauses present, or it matches one of the clauses and ends with cut and fail. The cut is written next to last so that it will not be executed unless all the other steps of the clause have succeeded first; as a result, it is still possible to backtrack from one clause of **g** to the other as long as the cut has not yet been reached.

In Prolog implementations that allow goals to be treated as data (and this does not include Turbo), the procedures **make_succeed** and **make_fail**, which make any goal succeed or fail, can be defined as:

```
make_succeed(Goal) :- call(Goal), !.
make_succeed(_).

make_fail(Goal) :- call(Goal), !, fail.
```

In some implementations, **call(Goal)** is written simply as **Goal**.

Likewise, the procedure **once** can be defined so that it allows a goal to succeed exactly once, thus making any goal a deterministic one:

```
once(Goal) :- call(Goal), !.
```

This procedure backtracks as much as necessary to get one successful solution to **Goal**, then stops. Thus, no matter how many possible solutions **f(X)** has, the goal **once(f(X))** returns only the first solution. If **f(X)** has no solutions, **once(f(X))** fails.

REPETITIVE COMPUTATION

Prolog offers two ways to perform computations repetitively: backtracking and recursion. Of the two, recursion is far more versatile. However, backtracking has some interesting uses, such as the construction of **repeat-fail** loops. In Prolog implementations that lack tail-recursion optimization, **repeat-fail** looping is the only kind of iteration that can be performed ad infinitum without causing a stack overflow.

The predicate **repeat** is built into most Prolog implementations. If not built in, it can be defined as follows:

```
repeat.
repeat :- repeat.
```

(The built-in version should be used if available, because in some implementations, the definition above does not prevent stack overflow.)

The **repeat** predicate always succeeds and has an infinite number of solutions. Thus, any procedure call bracketed between **repeat** and **fail** will be tried over and over again, even if it generates only one solution. For example, the following goal displays an infinite number of asterisks:

```
repeat, write('*'), fail.
```

The following procedure turns the computer into a typewriter, accepting characters from the keyboard and displaying them ad infinitum, until the the Break key is used to abort:

```
typewriter :- repeat,
              get0(C),
              put(C),
              fail.
```

The loop can be made to terminate by allowing it to succeed eventually, so that backtracking stops. The following version of **typewriter** stops when a line terminator (ASCII code 10) is typed:

```
typewriter :- repeat,
              get0(C),
              put(C),
              C = 10.
```

If C is equal to 10, execution terminates; otherwise, execution backtracks to **repeat** and proceeds forward again through **get0(C)** and **put(C)**.

The looping in the latter version of **typewriter** can be restarted by the failure of a subsequent goal (as in the compound goal **typewriter,fail**). To prevent the loop from restarting, a cut needs to be added as follows:

```
typewriter :- repeat,
              get0(C),
              put(C),
              C = 10,
              !.
```

In effect, this forbids looking for alternative solutions to **typewriter** once one solution has succeeded.

A crucial difference does exist between **repeat-fail** loops in Prolog and **repeat-until** loops in Pascal. In Pascal, iteration is accomplished by first executing all the statements in the loop, then jumping from the end back to the beginning. In Prolog, however, backtracking may cause control to jump backward from *any* goal to *any* earlier goal that has alternative solutions. (The limiting case is **repeat**, which does have alternative solutions.) If any goal in a Prolog loop fails, subsequent goals are not attempted.

A serious limitation of **repeat-fail** loops is that information cannot be conveniently passed from one iteration to the next. Prolog variables lose their values upon backtracking. Thus, there is no easy way to make a **repeat-fail** loop accumulate a count or total. (Information can be preserved by storing it in the knowledge base by using **assert** and **retract**, but this process is usually slow and awkward.) With recursion, information can be transmitted from one pass to the next through the parameter list. This is the main reason for preferring recursion as a looping mechanism.

RECURSION

Recursion is a familiar means of implementing task-within-a-task algorithms, such as tree searching and Quicksort. Prolog lends itself well to expressing recursive algorithms developed in LISP. However, *any* iterative algorithm can be expressed recursively.

Here is the classic recursive algorithm for computing factorials, as expressed in Pascal

```
function factorial(N:integer):integer;
begin
  if N=0 then
    factorial:=1
  else
    factorial:=N*factorial(N-1);
end;
```

and as expressed in Prolog (change **is** to = in Turbo Prolog)

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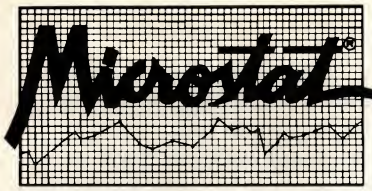

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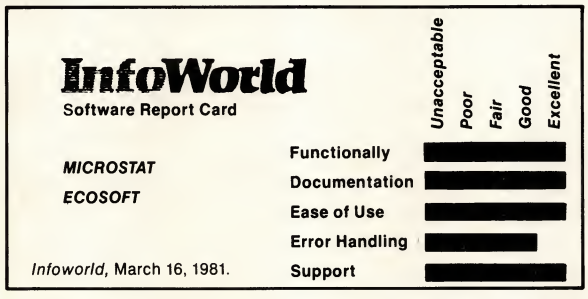

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```
factorial(0,1).
factorial(N,FactN) :- N > 0,
                      M is N-1,
                      factorial(M,FactM),
                      FactN is N*FactM.
```

This is straightforward; the procedure **factorial** calls itself to compute the factorial of the next smaller integer, then uses the result to compute the factorial of the integer in question.

Now consider an iterative algorithm to perform the same task:

```
function factorial(N:integer):integer;
var I,J:integer;
begin
  I:=0;
  J:=1;
  while I<N do
    begin
      I:=I+1;
      J:=J*I
    end;
  factorial:=J
end;
```

In Pascal, this procedure does not call itself. Its Prolog counterpart, however, is a procedure that calls itself as its very last step—a procedure that is said to be *tail recursive*:

```
factorial(N,FactN) :- fact_iter(N,FactN,0,1).
fact_iter(N,FactN,N,FactN).
fact_iter(N,FactN,I,J) :-
                I<N,
                NewI is I+1,
                NewJ is J*NewI,
                fact_iter(N,FactN,NewI,NewJ).
```

Here the third and fourth parameters of **fact_iter** are *state variables* that pass values from one iteration to the next. State variables in Prolog correspond to variables that change their values repeatedly in Pascal.

The recursive clause of **fact_iter** checks that **I** is still less than **N**, computes new values for **I** and **J**, and finally calls itself with the new parameters. The recursive call is the very last step in this clause; this whole clause is placed last so that when it calls itself, no untried alternatives will be left to save on the stack. This ensures that the stack will not grow during the iteration.

In Prolog (as in arithmetic, but not as in most programming languages), the statement **X is X+1** is always false. Because Prolog variables cannot change their values, the additional variables **NewI** and **NewJ** have to be introduced. **NewI** and **NewJ** contain the values that will replace **I** and **J** in the next iteration.

The first clause of **fact_iter** serves to end the iteration when the state vari-

ables reach their final values. A more Pascal-like, but less efficient, way of writing this clause would be:

```
fact_iter(N,FactN,I,J) :- I = N, FactN = J.
```

That is, if I is equal to N, then **FactN** (which has been uninstantiated until now) should be given the value of J. By writing this same clause more concisely in the earlier procedure, Prolog's unification mechanism is made to perform work that would require explicit computational steps in other programming languages.

Most iterative algorithms can be expressed in Prolog by following the pattern below:

- First, other types of loops (for example, **for** and **repeat-until**) are transformed into Pascal-like **while** loops.
- Then the computation is broken into three stages: the initialization, the loop itself, and any final computations needed to return a result.
- The loop as a tail-recursive clause (for example, the second clause of **fact_iter**) is expressed with the **while** condition at the beginning.
- The final computations is placed in another nonrecursive clause of the same procedure, which is set up so that the nonrecursive clause executes only after the loop is finished.
- Finally, the entire algorithm is hidden behind a "front-end" procedure (**factorial** in the above example), which is what the rest of the program actually calls.

The front-end procedure not only passes along its parameters into the tail-recursive procedure, but the initial values of the state variables as well. The fine art of expressing iteration through tail recursion in Scheme (a LISP dialect) is discussed extensively in *Structure and Interpretation of Computer Programs*, by Harold Abelson and Gerald Jay Sussman (MIT Press, 1985).

Whenever one Prolog procedure calls another, one or more pointers are saved on a pushdown stack. These pointers indicate what remains to be done after return (the *continuation* of the calling procedure) and what alternative solutions remain to be tried (the *alternative set*).

Because every single procedure call places information onto the stack, recursion would appear to lead inevitably to stack overflow. However, several Prolog implementations, including Arity and Turbo, recognize a special case: if both the continuation and the alternative list are empty, nothing need be placed on the stack at all. In this circumstance, instead of calling the next procedure in the normal way, the computer can simply jump into the next procedure without saving a record of where to return. If the procedure is calling itself, this effectively transforms recursion into iteration.

As was stated earlier, a procedure that calls itself with an empty continuation and empty alternative set is described as *tail recursive*; the process of executing such a call without adding any items to the stack is called *tail-recursion optimization* or *tail-recursion elimination*. (The "elimination" of tail recursion does not mean that it should be banished from the program entirely. On the contrary, tail recursion should be used liberally because the implementation transforms it into an efficient, iterative process.)

A quick way to verify that a particular Prolog implementation performs tail-recursion optimization is to try the following predicate:

```
test(N) :- write(N), nl, M is N+1, test(M).
```

Start with the goal **test(1)** and see how long execution continues. If the program runs for more than 10,000 iterations, it is a safe bet that tail-recursion elimination is taking place.

CONTROLLING STACK GROWTH

Recognizing a recursive call that has an empty continuation is easy: the recursive call is the very last subgoal in the clause that contains it. Determining whether the alternative set is also empty takes more thought.

One way to get an empty alternative set is to put the recursive call in the last clause of a predicate. By doing this, the recursive call takes place only after the other alternatives have been exhausted. An example is the longer iterative factorial program that was given earlier. The recursive call takes place only when all other alternatives have been exhausted.

In the third clause of the iterative factorial program, **fact_iter** calls only deterministic predicates (< and **is**) before calling itself recursively. In fact, if this clause had contained any calls to nondeterministic predicates, the alternative set would not have been empty at the time of the recursive call because this same recursive call possibly could have been reached by a different, as yet untried, path.

The alternative set can also be made empty by using the cut operation to rule out alternatives, as in the following replacement for **fact_iter**:

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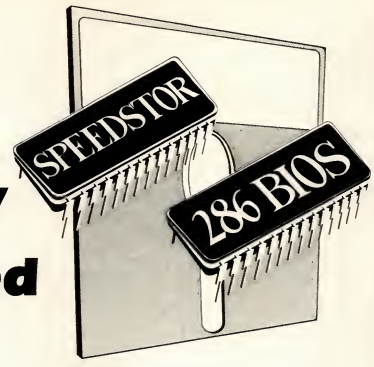

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```
fact_iter(N,FactN,I,J) :-
    I < N,
    NewI is I+1,
    NewJ is J*NewI,
    !,
    fact_iter(N,FactN,NewI,NewJ).

fact_iter(N,FactN,N,FactN).
```

Here the recursive call occurs in the first clause, but the cut guarantees that the second clause need not be considered as an alternative. Moreover, it does not matter whether the predicates that were called before the cut are deterministic or not; the cut rules out any backtracking through them.

This technique should be used with caution: it works in some Prolog implementations, including Turbo, but not all. In Arity Prolog 4.0, it appears to work in compiled programs, but, curiously, not in interpreted ones.

Finally, some Prolog packages empty the alternative set under certain conditions by looking ahead to other clauses. For example, the following program is tail-recursive in interpreted Arity Prolog even though it does not appear to be:

```
test(X) :- write(X), nl,
           NewX is X+1,
           test(NewX).

test(0).
```

When X is nonzero, the interpreter looks at the heads of both clauses before trying either. It sees that the second clause cannot work with nonzero X, so it enters the first clause with the alternative set empty. This mechanism, called *indexing*, is seldom well documented and should be tested thoroughly before it is relied upon.

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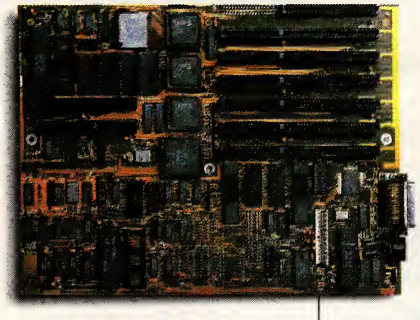

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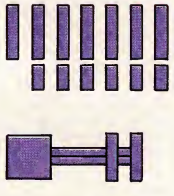

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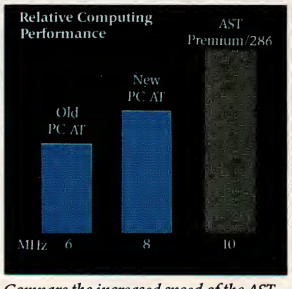

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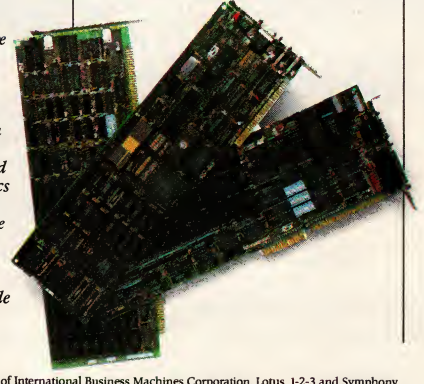

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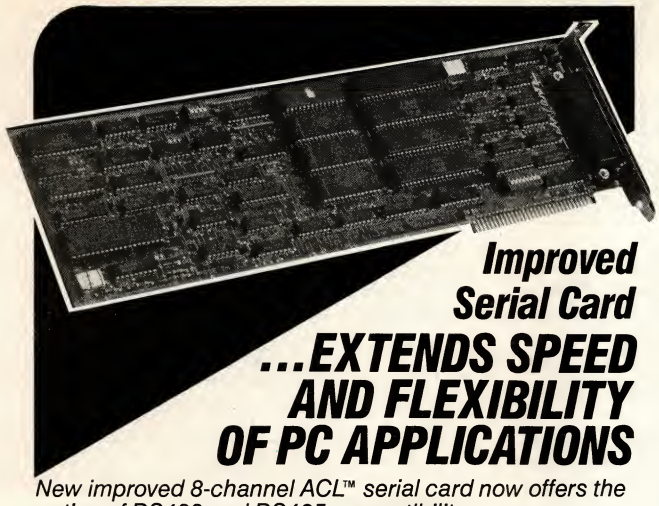

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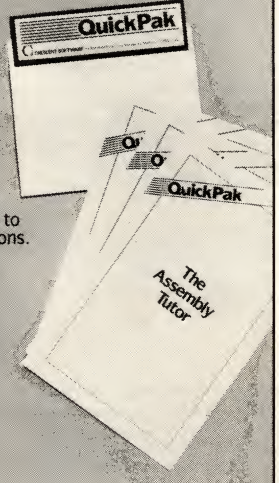

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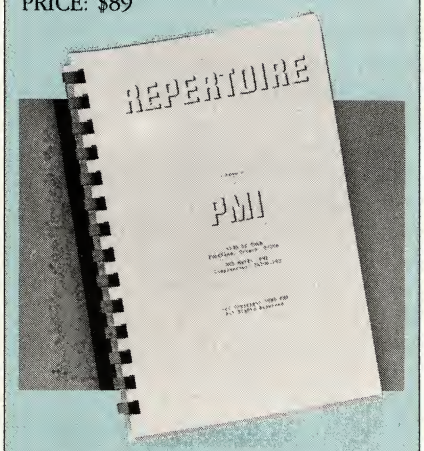

CIRCLE 351 ON READER SERVICE CARD

Modula-2 systems have not engendered the same toolbox generation that pervades the C and Turbo Pascal markets. Typically, most Modula-2 compilers come with a set of skeletal libraries. Users then create their own sets of higher level routines for screen management, extended I/O services, and graphics. To fill part of that need, PMI has introduced REPERTOIRE, a collection of high level tools for Modula-2 programmers. This package contains a screen management package with natural language analysis facilities, a screen editor, and a window oriented editor. Indexed file I/O and low-level services complement the package.

REPERTOIRE is designed to support two Modula-2 compilers—Interface Technologies Corporation's M2SDS and Logitech, Inc.'s Modula-2. (For a review of these products, see "Modular Development," John T. Cockerham, this issue, p. 114.) PMI delivers the routines on two diskettes or as a set of four for both compilers for an additional $20. The installation routines are well documented in the manual.

The REPERTOIRE manual is very complete and includes a comprehensive index. The writing is exceptionally clear. The copy, however, is less clear. The type is blurred and microscopic.

In a radical departure from most software companies, PMI also includes the Modula-2 source code in the base price. The author's stated purpose is to allow the user to support some of the code and reserve the difficult bugs for company support.

The use of the screen system starts by creating the screen template with a basic text editor. This template is a series of lines that indicate to the screen manager the screen number, data fields, colors, acceptable user responses, and the next screen in sequence. The specifications are fed to the screen compiler (its source code is included with the package) that creates a .DSP file. The programmer calls up a screen by calling the screen manager and specifying the .DSP file and the screen number. The screen manager interprets the contents of the .DSP file. Included with the screen manager is a simple, screen-oriented text editor that allows a uniform user interface for text entry.

The natural language facilities are actually a pattern expression evaluator. The pattern can include Boolean operations on the presence or absence of a string from the test string, the length of the test string, and the relative positions of words within the test string. The routine returns an index into the pattern string where the match occurred. For example, pattern string

'chicken' & 'pot' \ 'garage' & 'car'

defines two patterns. The first searches for *chicken* and *pot* in a string; the second searches *garage* and *car*. The expression evaluator returns 0 for no match, 1 for a match of the first pattern, and 2 for the second. For example:
A chicken in every pot returns 1.
Two cars in every garage returns 2.
Chicken potato pie returns 1.
A chicken in every car returns 0.

An option is provided to match only whole words, and the word-delimiting characters may be specified by the user. With appropriate user-written patterns, the string expression evaluator can be used to create a simple natural-language command interface.

PMI has written these routines to accommodate a multitasking environment. The windowing and screen-oriented text editor can be invoked by several user-written Modula-2 processes simultaneously; several editing windows can be open. Text exchange can be performed between the windows.

With version 1.3 of REPERTOIRE, PMI introduced an indexed file system. This system allows variable-length records and is quite fast. The file manager keeps the linked-list file index in RAM at all times, searching through RAM for the desired record. The index is updated only when the file is closed. An optional programmed mode saves the index with every update to the file. If the index is totally lost, a recovery mechanism automatically runs when the file is reopened, regenerating the index.

To overcome the differences between the two Modula-2 systems' implementations of low-level language facilities, PMI includes its own low-level routines. These routines fill in where the two implementations fall short. For the Logitech system, the routines provide long cardinal and long integer routines. For the Interface Technologies' system, the routines provide alternative implementations of the string functions.

The screen system is for text only. The text editor uses the F10 key to signal the end of data entry rather than the Enter key. Using the source code, this is a trivial change to make.

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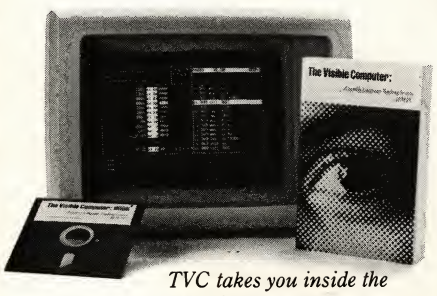

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In today's marketplace, very few manufacturers will take the risk of supplying the source code with their products, especially one as well conceived and well executed as REPERTOIRE. The routines offered in this package provide a Modula-2 developer with a useful set of high-level tools that are not available in the base language. They represent an outstanding bargain.

—JOHN T. COCKERHAM

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With the proliferation of hard disks comes an increased interest in programs that organize and manage hard-disk files and directories. FILEMAX is a disk management utility with an impressive set of features, including directory tree copying, directory renaming, file recovery, and disk optimization.

Unlike many popular utilities, FILEMAX is not a terminate-and-stay-resident program; it is intended to be invoked periodically, as needed, for directory viewing, organization, and clean up. An installation utility is provided to allow the user to modify program characteristics such as keyboard set-up, sound (on/off), and help file path. The FILEMAX program is not copy protected.

FILEMAX uses full-screen output and function-key command driven input. The output screen is split into two areas: the top 19 lines display outputs and the bottom 6 lines display prompts. A small menu in the lower left screen corner lists valid function keys and describes their use. On-line help is always accessible in FILEMAX with the F1 key. The help screens provide brief descriptions of options that are available at any point in the menu hierarchy.

FILEMAX's functions are in three categories: directory manipulation, file manipulation and display, and manipulation of the file allocation table (FAT).

Among the directory functions are commands to move, rename, create, delete, and sort directories. The move and delete functions are particularly powerful; using them the user can modify entire directory chains. The **move directory** command allows a directory to be inserted before, after, or within, that is, as a child subdirectory to any other directory. The **delete directory** command requests verification that the directory's files and all of the subdirectories are to be deleted. With the **sort** command directory entries can be sorted on any combination of name, extension, date, time, size, or attributes in either ascending or descending order by the sort field.

The supported file manipulation functions include copy, move, rename, delete, compare, change attributes, change date, and undelete. Files that originally occupied only one cluster can be recovered in one operation with the **undelete** command. For multicluster files, **undelete** allows the user to reconstruct the deleted file's cluster chain by selectively viewing available clusters and including the appropriate ones in the chain. Another function, **find string** command, searches for a specified character string in a file or range of files. Like all of the file functions, it allows the user to select a range of files upon which to operate.

The FAT analysis portion of FILEMAX provides a well-designed display of the FAT that shows the chaining of clusters in files, open clusters, bad clusters, and cross-linked clusters. The contents of any cluster can be viewed in either text or hexadecimal format.

An option called "tune up" allows the clusters on the disk to be reorganized in such a manner that all files are contiguously allocated on the disk and all subdirectories are placed at the beginning of the disk. However, the tune-up feature of the tested version reflects a possibly serious design flaw. As clusters are rearranged on the disk, FILEMAX keeps track in RAM of the corresponding changes to the FAT chaining and directory entries. This information is written to disk only at the completion of the tune-up operation. Any unexpected interruption of the operation, for example, from power loss or accidental rebooting can result in significant damage to the file structure of the disk, perhaps rendering it unreadable.

FILEMAX 3.42 contains another annoying bug that shows up when drive B: is referenced on a single-diskette-drive system. The program produces an error box that contains the message GX I/O ERROR and a display of registers, at which point the machine has to be rebooted. Using the **assign** command to assign B: to A: causes a similar problem.

FILEMAX has difficulty coexisting with some pop-up menu programs and device drivers. When Hersey Micro Consulting's FANSI-CONSOLE or the WordPerfect Library Calendar was installed before FILEMAX was started, the system hung when FILEMAX was exited. When FILEMAX is running, it directly uses the keyboard interrupt and does not pass through unrecognized keys (by calling the previous keyboard vector address).

The documentation for FILEMAX consists solely of a 19-page overview of program operation. Considering the complexity of the program and its capabilities, this is rather sparse information. Users familiar with DOS disk and directory structure, and who have used other disk utilities, such as the Norton Utilities, will make effective use of FILEMAX. However, the hierarchy of menus and functions is complex; even the veteran programmer will need time to master program operation.

—GLENN ROBERTS

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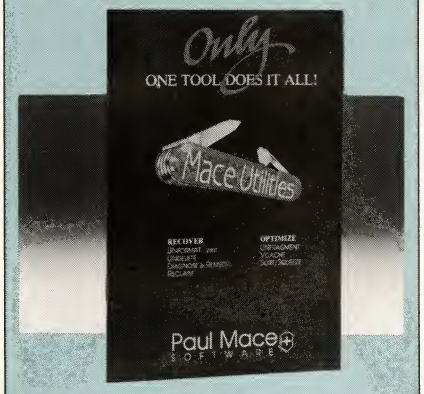

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Mace Utilities from Paul Mace Software will be of special interest to anyone who has ever accidentally formatted a hard disk that contained valid data. Mace Utilities can reconstruct a hard disk after a format, and more.

The IBM description of the DOS FORMAT command has a dramatic caution warning users that formatting destroys all of the data on the target disk. However, the *DOS Technical Reference* manual states, "When formatting a fixed disk, FORMAT checks all locations within the DOS partition, but does not physically format them again."

The FORMAT procedure consists of two distinct operations: physical formatting and logical formatting. Physical (or low-level) formatting, which is performed only on diskettes, builds the skeleton (the so-called *sectors*) onto which a logical DOS disk structure is built. The hard disks are already physically formatted when shipped by IBM. Logical (or high-level) formatting of a hard disk actually consists only of analyzing it for any defective areas, and of preparing it to accept DOS files by initializing the root directory and the file allocation table (FAT).

IBM's caution is not entirely accurate because FORMAT does not destroy

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a hard disk's data area. The root directory and FATs are cleared with zeros, but data previously placed on the disk are still there and may be recovered.

Because the content of a subdirectory is stored as a file within the data area, subdirectories are not destroyed by FORMAT and also can be recovered. All that is lost during a format is the original root directory pointer to the subdirectory "file." A well-designed program can examine a freshly formatted disk and find "files" that are probably subdirectories. The Mace Utilities package is designed to do just that.

Mace Utilities consist of one program (RXBAK.EXE) that is to be executed periodically and another series of programs that are driven from a menu system. RXBAK takes a snapshot of the hard disk's DOS partition boot sector, the FATs, and the root directory. This snapshot is copied into a special file that is stored at the logical end of the DOS partition. If a hard disk is accidentally formatted, Mace can copy this file back into the respective sectors from which it was created, thus restoring the directory to the state it was in the last time RXBAK was run. In most cases, this will allow the reclamation of some, if not all, of the lost data.

Because RXBAK takes only a few seconds to run, a call to it can be placed within any frequently used batch file. It can preserve many hours of work by safeguarding critical data structures. Note that these file recovery methods are only salvage operations, and because of that, the restored disk should be formatted once again after the recovered files have been safely transferred to another device.

Even if it is not installed on the hard disk, Mace can be run from the diskette to recover data lost due to an accidental FORMAT. Mace is not able to recover any files that were in the root directory. They probably still do exist; however, all pointers have been lost as a result of the clearing of the directory and FAT. Although Mace does not know where DOS placed subdirectory files, it does know in general what they look like. Mace searches the entire disk looking for possible subdirectory candidates. Once subdirectories are located, all files and subdirectories can be partially, if not fully, recovered. Restored first-level subdirectories will appear in the reconstructed root directory as SUB1, SUB2, SUB3, etc. Inside each SUB*n*, lost files can be found.

Mace Utilities contain several other useful functions for both diskettes and hard disks; these include the usual **file undelete** function and the more ambitious **diagnose**, **remedy**, **squeeze/sort directories**, and **condense** functions. **Diagnose** attempts to read every sector of a disk looking for errors. If it finds a sector that it cannot read correctly and that has not been previously marked as bad (in the FAT), it issues a message advising that this file should be attended to at once. **Diagnose** does not repair the disk; the **remedy** function is designed for that purpose.

Remedy is similar to **diagnose**, except that unreadable files are made readable with a minimal loss of data. If an unreadable sector is found within a cluster that is not allocated, it is locked out (in the FAT). If, however, an unreadable sector is part of some file, all readable sectors within a cluster are reconstructed and copied to another free cluster. The unreadable sector is filled with asterisks (*), and the FAT chain is relinked. Finally, the cluster containing the bad sector is locked out. If the file

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that contains the bad sector is a .BAT, a .COM, or a .EXE file, an error message is issued to the effect that this program probably will no longer execute properly and should be replaced. It should be noted that the actions taken by **remedy** are permanent; therefore, it normally is run only after **diagnose** has been used to gather information about the damaged files.

Squeeze/sort directories sorts the entries within a directory on one of the four fields (name, extension, date/time, or size) and moves all active directory entries to the top of the directory. This allows DOS to search through directories without the time-consuming process of reading and analyzing entries for nonactive (deleted) files.

As an option, **squeeze/sort** can set a flag within directory entries of .BAT, .COM, and .EXE files to "read only." This prevents them from being deleted (this effect can be reversed with the DOS command ATTRIB) and also enhances the performance of subsequent runs of the **condense** option.

Condense performs all of the diagnostic and repair operations described above, and then rearranges the files into a linear space. When it is finished, the files are contiguous (with the exception of bad sectors) and packed from the front of the disk. The order of packing is directories, read-only files, and then all other files. Directories are now close to the root, which means the seek time will be minimized. Most executable files are never operated on; they are merely read. **Condense** then packs all of the read-only files to the front of the disk, where they are close to the subdirectories and in one contiguous segment. This implies that they can be accessed rapidly.

The utilities Vcache, Vkette, and Vscreen have been added to version 4.0 of Mace. These programs are designed to speed up hard disk and diskette transfers and output to video displays.

The documentation with Mace Utilities is adequate, and in some cases it provides more information than users will want. On-line help is available; estimated runtimes as well as function descriptions are provided.

For $99, users can invest in a fairly comprehensive insurance policy for recovering lost files. Mace Utilities may not be able to recover all of the information, but the product is able to salvage a great deal of lost data, and that is a worthwhile dividend.

—GUY QUEDENS

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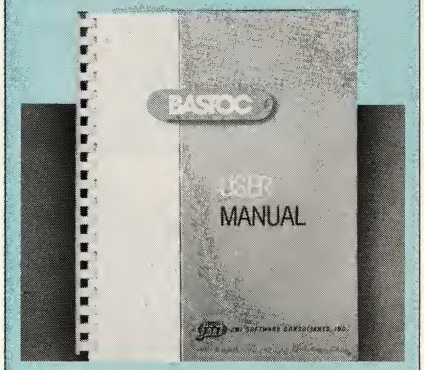

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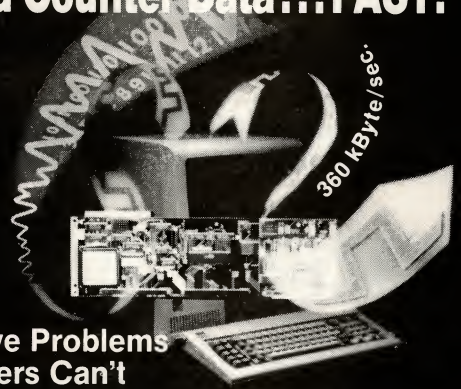

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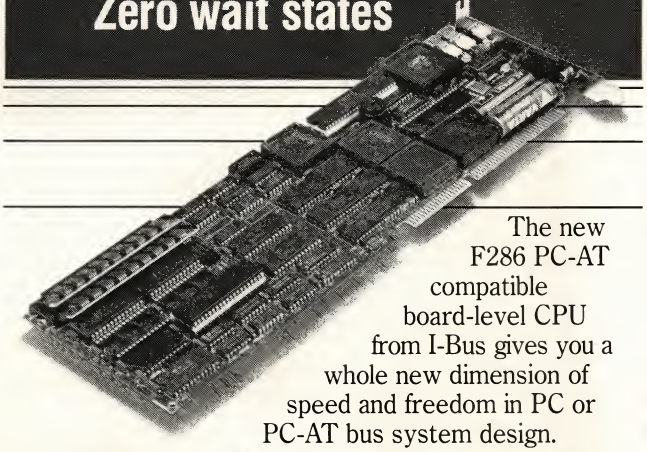

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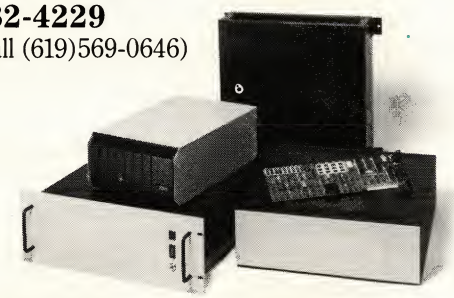

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CIRCLE NO. 210 ON READER SERVICE CARD

FIGURE 1: *BASIC Sieve of Eratosthenes*

```
090 REM       for PC-BASIC, BETTER, PROFESSIONAL
095 REM
100 DEFINT A-Z
110 LIM = 8190
120 DIM FLAGS(8191)
130 PRINT TIME$
140 FOR I=0 TO LIM
150   LET FLAGS(I) = -1
160 NEXT I
170 PRINT TIME$
180 FOR I=0 TO LIM
190   IF FLAGS(I) = 0 THEN 270
200   PRIME = I+I+3
210   LET K = I+PRIME
220   WHILE K <= LIM
230     LET FLAGS(K) = 0
240     LET K = K + PRIME
250   WEND
260   LET COUNT = COUNT + 1
270 NEXT I
280 PRINT COUNT; "PRIMES"
290 PRINT TIME$
```

The classic Sieve of Eratosthenes benchmark program was used as a simple test of BASTOC's conversion capabilities.

FIGURE 2: *BASTOC-Translated Sieve in C*

```
char *TIME_();
static int FLAGS[8192], count, i, k, lim, prime;
static int it_1, it_2;
static char *st_1;
main(argc, argv)
    int argc;
    char *argv[];
    {
    bio_init(argc, argv, 1);
    /* for PC-BASIC, BETTER, PROFESSIONAL */

    lim = 8190;
    BPRINT("s", TIME_(&st_1));
    it_1 = lim;

    for (i = 0; i <= it_1; ++i)
     {
     FLAGS[i] = -1;
     }
    BPRINT("s", TIME_(&st_1));
    it_2 = lim;

    for (i = 0; i <= it_2; ++i)
     {
      if (FLAGS[i] == 0)
         goto l_270;
     prime = i + i + 3;
     k = i + prime;
     while (k <= lim)
         {
         FLAGS[k] = 0;
         k = k + prime;
         }
     count = count + 1;

l_270:;
     }
    BPRINT("i;s", count, "\006PRIMES");
    BPRINT("s", TIME_(&st_1));
    bexit(0);
    }
```

The IF-THEN of the BASIC program was changed to a C goto statement. The rest of the program is well structured.

addressed by BASTOC, a software package from JMI Software Consultants, Inc. BASTOC accepts a BASIC program in source form as input and creates equivalent C source code from it. (BASTOC was originally reviewed in "BASIC to C," Ernest Tello, October 1984, p. 117.)

BASTOC is intended as both a migration utility (making a one-time conversion of a program from BASIC to C) and as a production BASIC compiler that produces a C program as its output (for use in developing prototype or throwaway programs). The BASTOC package consists of a translator program and a runtime library in small and large memory models. The library contains support for dynamic string handling (a feature not normally found in C), screen control, and BASIC-style file I/O. The module ANSI.SYS must be present to use BASTOC's screen routines.

C source code is provided for the runtime library, several translator functions, and data tables. The package is shipped with four diskettes and an 8½-by-11-inch spiral-bound manual. BASTOC is not copy protected.

Installation of the program is a straightforward procedure that is well documented in the manual. It consists of copying the files on the supplied diskettes to a single directory. Following installation, the directory includes two versions of the translator program, one that simply produces a C source file as output and another that acts as a complete compiler, calling the Microsoft C compiler and linker directly after source translation. Also included in the directory are the runtime library in the appropriate memory model and a main program that handles intra-program chaining and COMMON variables.

BASTOC supports the BASIC.EXE (not the advanced BASICA) version of Microsoft BASIC for the PC. Statements that are not supported include PEEK, POKE, and VARPTR for large memory models (implying that assembler language subroutines need manual conversion), and all of the BASICA graphics and sound statements. The CHAIN, COMMON, RUN, and SHELL statements also have some restrictions. For most business software, this should prove to be an adequate subset of BASIC.

Notably absent from BASTOC is support of the more recent Microsoft QuickBASIC and IBM BASIC Compiler version 2.0 enhancements, such as separate subroutines and ISAM files. In its current version (2.1c), however, BASTOC has added support for some features it previously rejected: NEXT instead of NEXT *variable*, use of % for specifying integer variables, and READ...DATA.

The BASTOC options control code optimization (including detecting and deleting unreachable code), default variable types, program organization, and subroutine handling (GOSUBs can be left in-line in a single, monolithic function or isolated into separate C functions). An new option in version 2.1c optimizes expressions by using C's increment and decrement operators wherever possible. Wild card file processing is not available.

The code translated by BASTOC for the BASIC version of the Sieve of Eratosthenes (see "The State of C Interpreters," Marty Franz, May 1986, p. 153 and "Reconsidering BASIC," Marty Franz, December 1986, p. 142) is shown in figure 2, with the original BASIC version in figure 1. A C **goto** statement and matching label have been added where the GOTO existed in the original program. The TIME_ function may need to be rewritten for some compilers. In general, the resulting C program is well-structured and fairly portable.

Within the above framework, operation of BASTOC is straightforward and produces no surprises when the Microsoft C compiler and linker are used. Other compilers may require modification to the runtime library. Most of the library functions are available in source form and are adequately documented by JMI; a knowledge of C is required to make the modifications. The more unstructured the BASIC source code is, the more unstructured the C output will be, especially when GOTOs and GOSUBs are used carelessly. A disciplined BASIC coding style is the way to ensure that the C code generated by BASTOC can be maintained.

An important feature of the BASTOC package is the translator, which can be modified and rebuilt to handle additional functions and statement types. This gives it the potential for translating other BASICs, such as QuickBASIC, into C. Hooks have been provided into the translator's key-word tables and recognition routines to allow user-written functions to be added, but this has not been well-documented in the manual and must be considered a technical challenge to even an experienced C programmer. Nonetheless, it should prove easier to extend BASTOC than to write a comparable translator from scratch. BASTOC is a competent programming tool for programmers converting large BASIC systems to C.

—MARTY FRANZ

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The report analyzes each NIC according to its access scheme, raw bit rate, on-board processor and NIC-to-host transfer method.

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To Get the Reports.

The *LAN Operating System Report 1986* and the *LAN Evaluation Report 1986* are available free of charge from Novell. To obtain a copy of the Novell Report Package, call or write Novell Corporate Communications, 122 East 1700 South, Provo, Utah 84601, (801) 379-5900.

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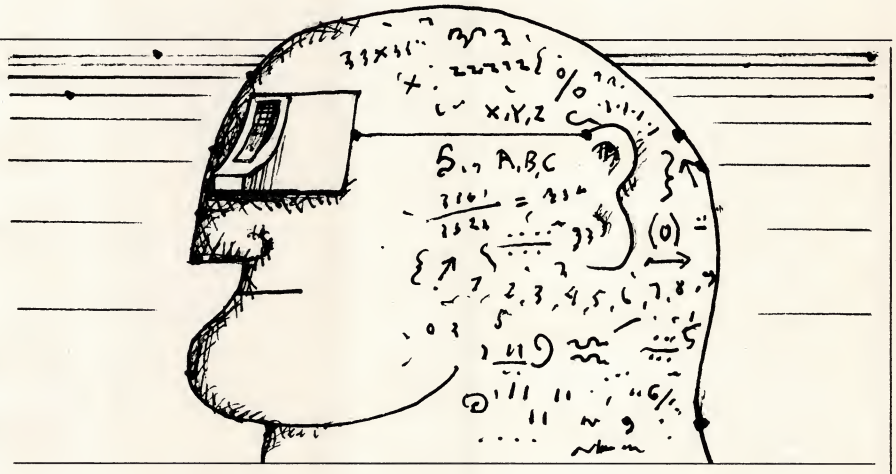
RICHARD L. SCHWARTZ and ROBERT E. SHOSTAK

What Computers Cannot Do

Certain mathematical problems simply cannot be solved by computer, no matter how big the program or how much time is available.



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Artificial intelligence is usually defined as a set of techniques for programming computers in a way that confers some of the attributes of human intelligence. The degree to which this endeavor will be successful is, of course, an open question. In principle, there is no reason why computers cannot be made as intelligent or more intelligent than humans—indeed, the human brain appears to be nothing more than a massively parallel personal computer based on some inexpensive organic logic. A much more interesting theoretical question is not whether computers can do what people do, but rather what is it that computers can compute, human or otherwise.

Ironically, the question of what types of problems can be solved purely through mechanical means was first posed long before the modern computer even came into existence. A great deal of attention was given to this issue in the 1920s and 1930s by a group headed by the well-known mathematician David Hilbert. While Hilbert and his colleagues had never heard of FORTRAN, they nevertheless understood the concept of a program, or algorithm. Their dream was to mechanize all of mathematics so that a single algorithm could solve any problem that could be stated in a mathematical way.

Hilbert and his associates made a certain degree of progress in the early 1930s by devising general algorithms that could solve certain classes of problems in mathematical logic. These early results were quite encouraging, and for a while it looked as if the livelihoods of unborn generations of computer programmers might be in jeopardy.

In 1936, however, hopes for implementing Hilbert's grand scheme were abruptly dashed by the logicians Alonzo Church and Alan Turing. Using different approaches, they proved that the so-called universal algorithm cannot exist. In fact, a consequence of what they demonstrated is even more remarkable: certain classes of problems in mathematics simply cannot be solved with computer programs, no matter how big the program or how much computer time is available.

Their arguments rest on a certain assumption that has come to be known as *Church's Thesis*, which, in essence, postulates that the instruction set of a very simple hypothetical computer known as the *Turing Machine* is powerful enough to use in coding any algorithm that could ever be programmed on any computer, existing or future.

The Turing Machine consists of a tape transport with an infinite tape, a read/write head, and a finite-state controller. The tape is divided into individual cells, each of which can store one bit of information. The read/write head scans a single cell of the tape at a time. The transport has the ability to move the tape one cell to the left or right upon the command of the controller. As might be expected, the controller is, at any given time, in one of a certain number of states. One of these is designated as the Start state; another is known as the Halt state.

The operation of the machine is quite simple. At each step, the read/write head reads the currently scanned cell of the tape. On the basis of the current state and on what is read, the controller either writes a bit to the tape or moves the head left or right one cell. In either case, it transits to another (possibly the same) state. Execution begins in the Start state and terminates in the Halt state. The input to the machine is encoded as the initial configuration of the tape; the output is given by what remains on the tape when the machine enters the Halt state.

The operation of the controller can be summarized by a table (think of it as a program) that lists the state and head transitions. Figure 1, for example, shows a Turing Machine program that takes a positive integer as input, and multiplies it by two. An integer x is encoded on the tape as a sequence of $x + 1$ 1s, with 0s everywhere else. As shown in the figure, the states of the machine are designated q_0 through q_8, with q_0 as the Start state and q_8 as the Halt state. Each entry in the table is a quadruple specifying the current state, the value of the currently scanned cell, a write or move action, and the next state that is to be entered. For example, the quadruple $q_4 0 R q_5$ specifies that if the machine is currently in state q_4 and scans a 0, it should move one cell to the right and enter state q_5.

As an exercise, the operation of the machine can be simulated for an input

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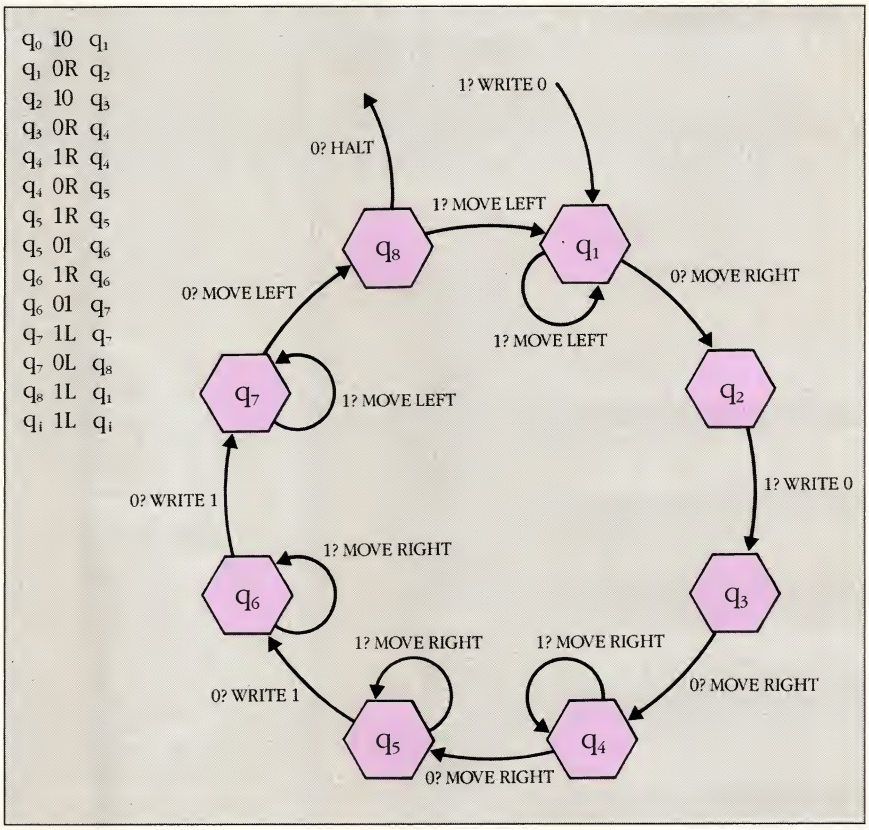
FIGURE 1: *Turing Machine Program*



Each entry is a quadruple specifying the current state, the value of the currently scanned cell, a write or move action, and the next state to enter.

of 2 (input tape ...01110...). Assume that the read/write head is initially positioned at the first 1. The quadruples can be grouped into subroutines for performing actions, such as erasing an input digit or adding new output digits.

With a little effort, a Turing Machine program can be written to multiply two numbers. More remarkably, and with quite a bit of effort, a Turing Machine can be programmed to emulate the operation of a Cray supercomputer. In fact, because a Turing Machine has an infinite tape, while the Cray's secondary storage is finite (at least, as it comes from the factory), the argument could be made that the Turing Machine is actually more powerful than a Cray. The important point, however, is that even if the Cray had an infinite secondary storage, it could not compute anything that could not be computed, given enough patience, using a simple Turing Machine.

Church's Thesis actually goes one step further. It says, in effect, that no matter what new hardware technology comes along, we will never be able to compute what we cannot compute now, given enough disk space and patience. Of course, this thesis is only a conjecture—it cannot be proved, and, in fact, it cannot even be stated in a precise, mathematical way. Still, it seems quite plausible, and at least so far, it has stood the test of time.

What Turing showed specifically was that it is not possible to come up with an algorithm that solves the so-called *halting problem*—determining whether a given computer program terminates (as opposed to looping forever) on all inputs. Imagine writing an assembly language program on the PC that reads a file containing an arbitrary Pascal procedure and determines if there is some input for which that procedure just loops forever without terminating. In fact, no such 8086 program exists—none could be written even if it could be arbitrarily large (but finite) and could take advantage of an infinite amount of disk space.

Of course, Turing had never heard of an 8086 or Pascal. He phrased the halting problem in terms of Turing Machines. How did Turing prove that the halting problem could not be solved? The answer is by using a clever technique known as *diagonalization.*

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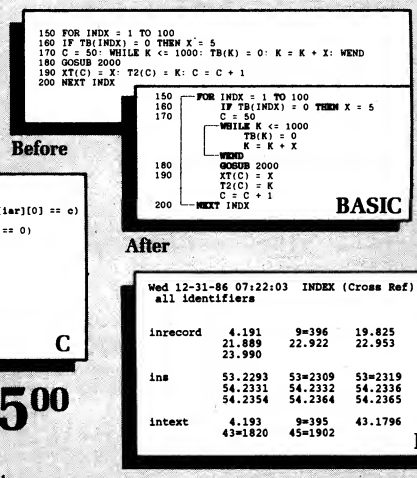

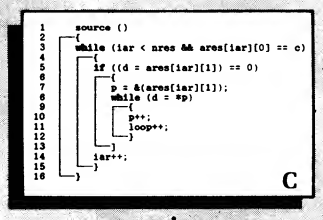

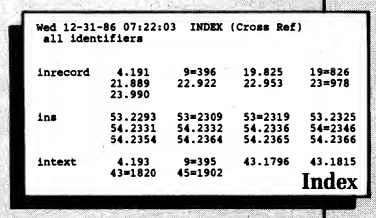

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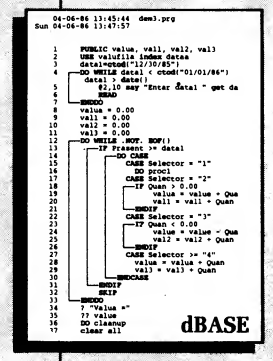

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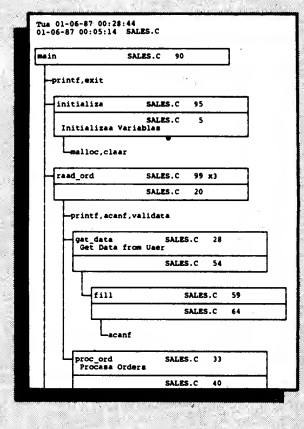

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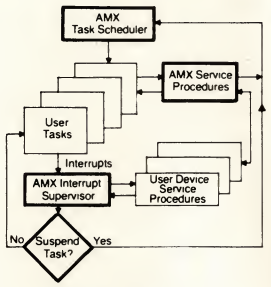

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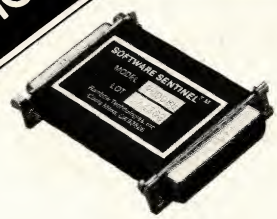

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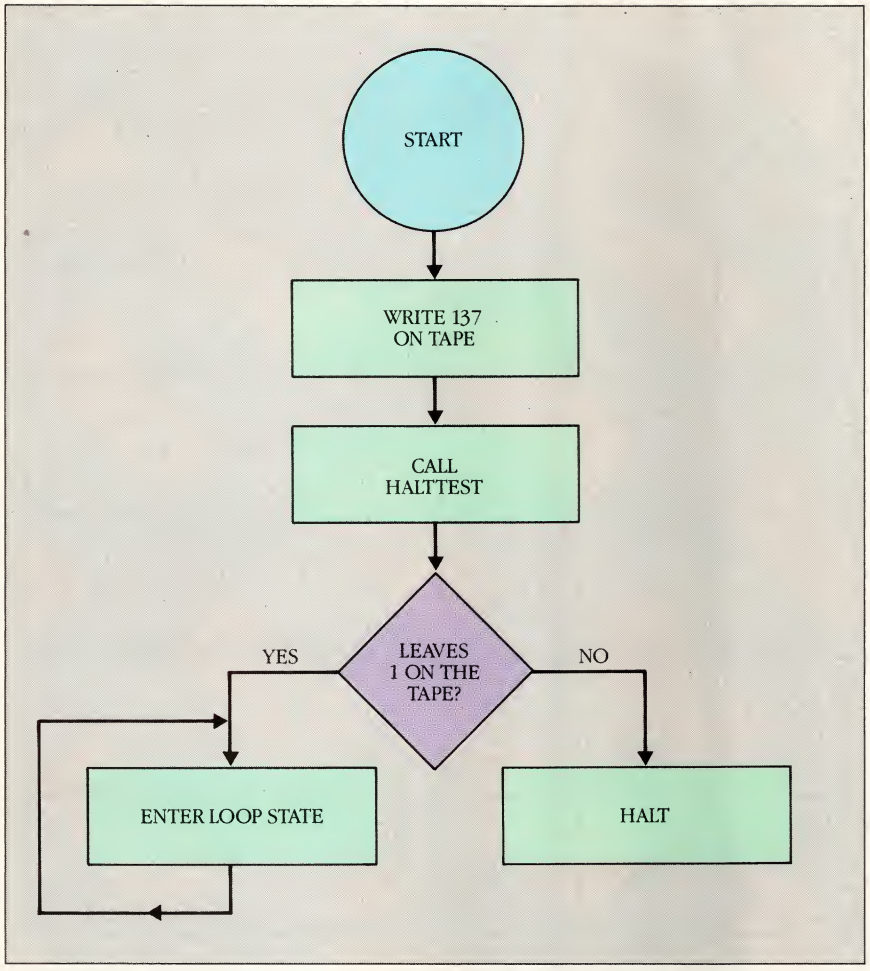
FIGURE 2: *Flowchart for KILLER*



Assuming that its Goedel number is 137, KILLER calls HALTTEST with 137 as an argument. If the call to HALTTEST leaves a 1, KILLER loops forever.

Here is the essence of the argument. First, in principle, all possible Turing Machine programs can be enumerated and assigned an integer. Naturally, an infinite number of such programs exists, but, nevertheless, no more than the number of available integers. Such an enumeration of all possible programs is called a *Goedel numbering*. Goedel numbering is the theoretician's version of the story about the comedians who tell the same jokes over and over so often that they simply assign each joke a number. (Someone calls out 45, and only one comedian laughs—he had not heard it before.)

Suppose that a Turing Machine program could solve the halting problem. This program (call it HALTTEST) could take as its input the Goedel number of an arbitrary Turing Machine program and determine whether or not that program halts on all inputs. If so, it would leave a 1 on the tape; if not, it would leave a 0.

Next, consider a powerful and easy-to-use program named KILLER that calls HALTTEST as a subroutine, as shown in figure 2. (To be completely rigorous, KILLER should be specified as a set of quadruples; the flowchart shown in the figure is an abbreviation.) Assuming that its Goedel number is 137, KILLER ignores its input and just calls HALTTEST with 137 as an argument. If the call to HALTTEST leaves a 1, KILLER loops forever; otherwise it quits, leaving a 0 on the tape.

Either way, a contradiction is apparent. Because HALTTEST halts on all inputs, KILLER hangs if and only if HALTTEST(137) leaves a 1 on the tape. But by definition of HALTTEST, HALTTEST(137) leaves a 1 on the tape if and only if KILLER never hangs. The conclusion, therefore, is that such a HALTTEST program cannot exist. This argument works just as well for 8086s as it does for Turing Machines. Because 8086s are so complicated to describe,

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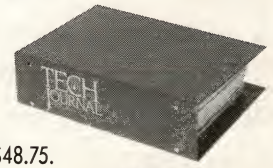

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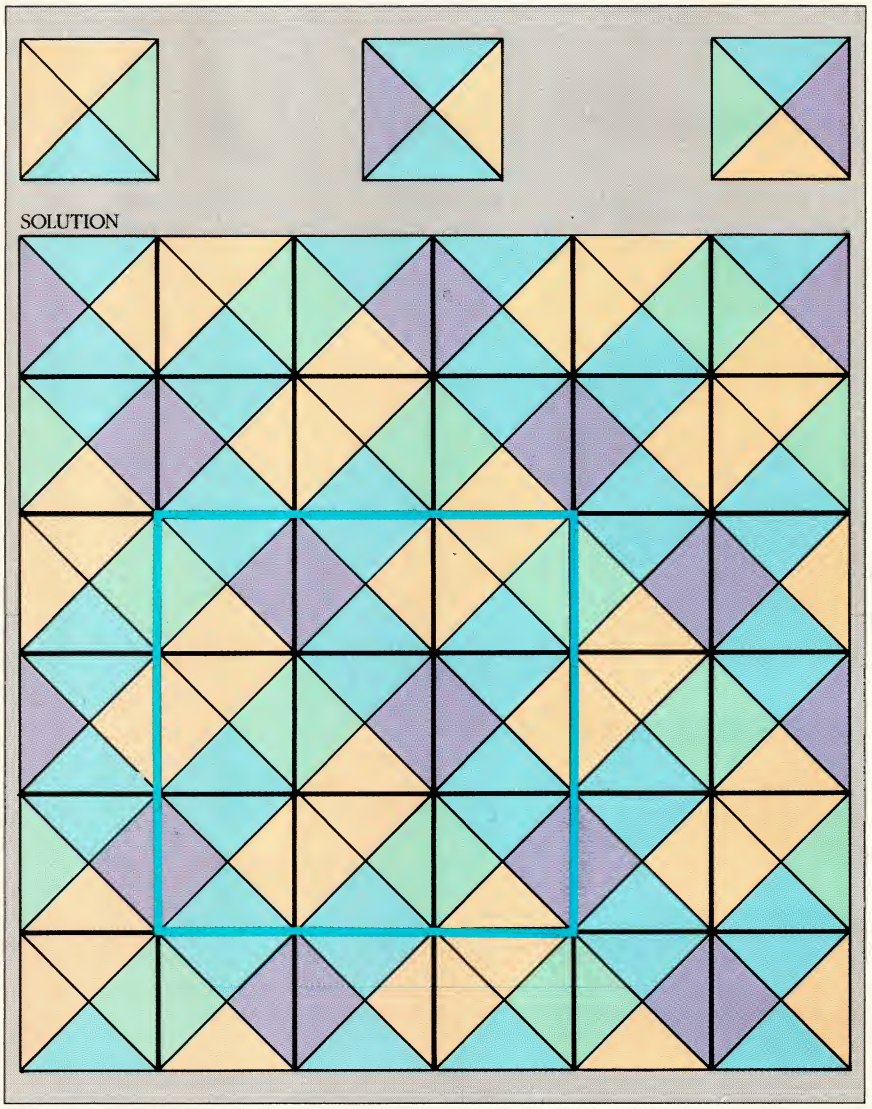
FIGURE 3: *Domino Example and Solution*



To solve this set of dominoes, a pattern is generated (inside blue square) whose left and right edges have the same color sequences, as do the top and bottom.

however, it is easier to give a rigorous formulation for Turing Machines.

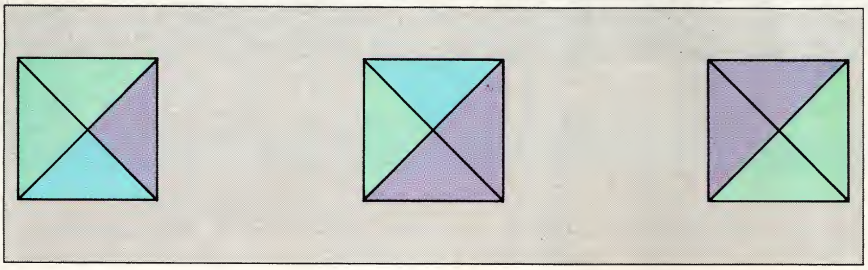
The halting problem is the prototypical instance of certain problems in theoretical computer science known as *decision problems*. An infinite class of yes-no questions is said to be *decidable* if and only if a computer program can be written that is guaranteed to answer each question in the class.

The *undecidability* of the halting problem has implications for fundamental questions in mathematics and logic. For example, the principle underlying this result is the basis of the well-known Goedel's Incompleteness Theorem, which states that certain mathematical truths simply cannot be proved. The consequences are not merely of theoretical interest, however. Believe it or not, the inability to solve the halting problem imposes limits on how well compilers can optimize compiled code. More generally, it limits the ability to write programs that can analyze other programs. It implies, for example, that programmers can never hope to write a single, general-purpose program that determines whether or not a piece of code contains bugs.

SOLVABLE DOMINOES

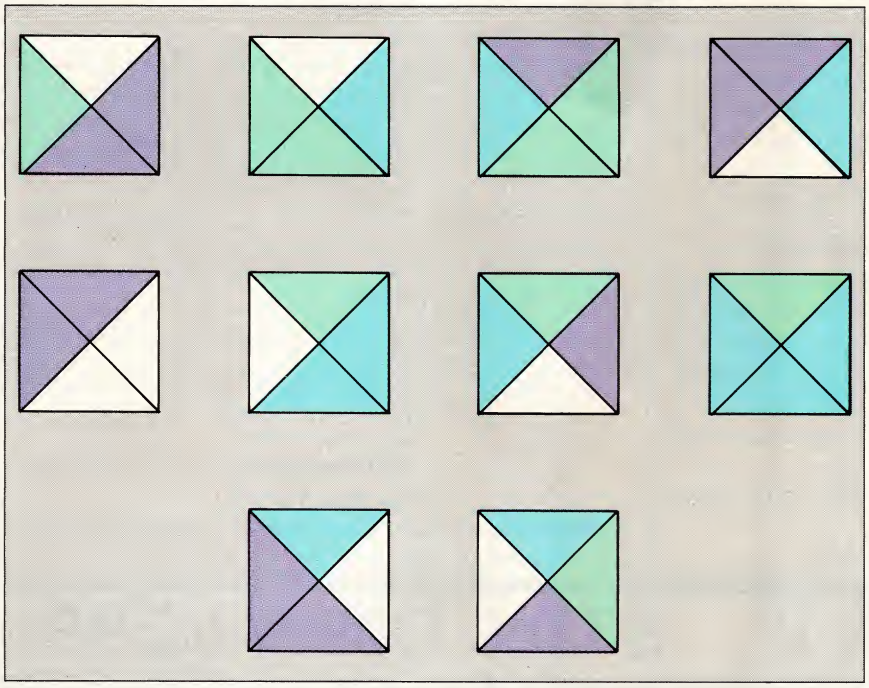
An interesting game was devised by Hao Wang at Bell Laboratories just for the purpose of studying the halting problem and other questions of decidability. Wang's game is a variation of solitaire played with colored tiles he refers to as *dominoes*. His dominoes are square-shaped and are painted in such

FIGURE 4: *Three-piece Domino Problem*



No general method exists for determining whether or not a given set of dominoes has a solution. This three-piece set may or may not be solvable.

FIGURE 5: *Ten-piece Domino Problem*



Even without using a general method, a player can still try ad hoc approaches to determine whether or not a particular set of dominoes can be solved.

a way that each of the four sides can be a different color. Moreover, each square has a definite orientation—that is, it cannot be rotated. In this domino game, players are given a finite set of dominoes of which they are allowed to make as many copies as they wish. The object of the game is to cover an infinite plane with dominoes in such a way that adjacent edges are the same color. If the entire plane can be covered in this way, then the set of dominoes is said to be *solvable*.

Figure 3 shows a set of three dominoes. This particular set is solvable, because it can be used to tile the plane using the pattern also shown in figure 3. The pattern is generated by repeating a nine-domino unit whose left and right edges have the same sequences of colors, and whose top and bottom edges also follow the same color sequences. Clearly, any time a repeatable unit of this type can be formed, a solvable set is possible. (It is possible to show, however, that some solutions to domino problems do not consist of a repeating block.)

Wang was able to use dominoes to simulate Turing Machine computations and therefore to create the equivalent of the halting problem. Wang and his colleagues showed that for a given Turing Machine program, a set of dominoes can be devised that has a solution if and only if that program hangs. His construction starts with the table of quadruples giving the program and generates dominoes that simulate the action of reading the tape, making state transitions, and so on. Because the halting problem is undecidable, it follows that no general method exists for determining whether a given set of dominoes has a solution.

Even without a general method, ad hoc approaches still can be used to determine whether or not a set of dominoes has a solution. Figures 4 and 5 present two sets of dominoes that may or may not be solvable. Solutions or arguments for unsolvability of these sets will be published in our next column.

While Wang's reduction is too complex to detail here, it should be noted that an important step along the way was the observation that a particular set of dominoes can tile the entire plane if and only if it can tile a single quadrant. Obviously, given that a player can tile the whole plane, he can cut out three of the four quadrants in order to find a solution for a quadrant. The converse is by no means obvious, but can be established by noting that a tiling for a quadrant necessarily contains a subtiling of size n-by-n, for each n. An infinite tree of these partial solutions can be constructed, and an infinite path can be found through the tree in order to yield a solution that covers the entire plane. Therefore, if a quadrant can be tiled, so can the plane.

Wang's games of dominoes were not merely of recreational interest. He was able to use them in order to close what was then an open question in mathematical logic. Specifically, he showed that the problem of determining the validity of members of a certain class of logical formulas can be simulated using dominoes. The formulas in question have the form "There exists an x such that for all y, there exists a z such that. . ." followed by a subformula containing no "for all" or "there exists."

Perhaps the greatest importance of Wang's dominoes is that they vividly illustrate an important technique used in many computer science disciplines and particularly in artificial intelligence—that is the technique of solving a problem by reducing it to another problem whose solution is already known. The domino reduction actually uses a contrapositive form of that technique, in which a given problem is shown to have no solution by reducing another problem (the Halting problem, in this case) that is known to be intractable to the given problem.

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reference book on this modern descendant of Pascal. Edward J. Joyce's *Modula-2: A Seafarer's Guide and Shipyard Manual* goes only partway toward achieving this goal. Its relaxed, conversational style provides welcome relief from the dry, formal writing of the definitive Modula-2 text, *Programming in Modula-2* by Niklaus Wirth, the original designer of the language. Wirth's book, which is filled with Backus-Naur notation and cryptic writing, is almost too concise to be readable.

program is the only example that is given in the text of Modula-2's separate compilation facilities.

The book does not present a cohesive picture of the standard Modula-2 function libraries for file and terminal I/O, dynamic memory management, real math functions, and so on. These libraries are not guaranteed to be identical across implementations, so it is rather important to distinguish between base language features and features of the library modules. This important distinc-

As the authors present each feature of Modula-2, they are careful to discuss not only its syntax, but also the reason for including it in the language; the reader is not left to guess the intentions of the language designer.

Ford and Wiener present many relevant examples, and the sample programs illustrate well both the syntax of the language and the software development concepts (data and procedure abstraction, information hiding, and so on) that Modula-2 was, in fact, designed

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to support. Complete listings of several Modula-2 utility libraries (modules) are included; among them are complex number, stack, queue, and character string modules, each of which is implemented several different ways. Also listed are modules implementing dynamic memory allocation, process synchronization, and a simple text editor with a spelling checker.

The book mentions several shortcomings of the language (such as its lack of support for generic data abstraction), but emphasizes possible solutions and work-arounds, not the problems themselves. For example, when noting the very primitive nature of Modula-2's concurrent processing facilities, the authors provide listings of modules to handle shared variables, interprocess buffers, and channels, giving an outstanding example of Modula-2's flair for software tool building.

Although *A Software Development Approach* is concise and well-organized, it sometimes goes into more detail than is really necessary. For example, as they discuss dynamically-allocated data structures, Ford and Wiener explain the difference that exist between singly and doubly linked lists; this is not the material of a programming language text or even a text on software development, but rather one on basic data structures and algorithms. Wirth's own book on algorithms and data structures in Modula-2 was reviewed in "A Classic Revised," Book Reviews, Michael A. Covington, January 1987, p. 187.

This book is not ideal for those programmers who know Pascal and want to get up to speed quickly in Modula-2. However, such programmers should be able to skim the early chapters in order to understand the differences between Modula-2 and its predecessor, Pascal. Unfortunately, this text does not provide a summary of the differences between the two languages.

A Software Development Approach emphasizes software development so extensively that it would not be difficult to substitute another language, say Ada, for Modula-2 in the text. This is not to say that the book's description of Modula-2 is not accurate and complete; in fact, it makes a compelling argument for Modula-2 largely because it emphasizes principles of good software engineering. This book is a good reference for the serious Modula-2 user and an excellent introduction to the language for anyone considering using Modula-2 for a programming project.

—ARTHUR A. GLECKER

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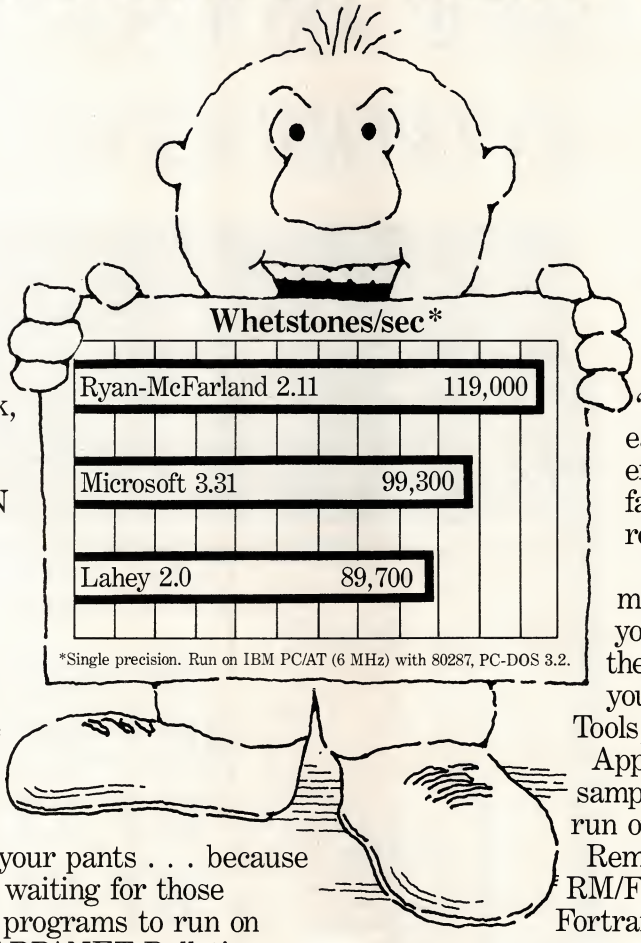

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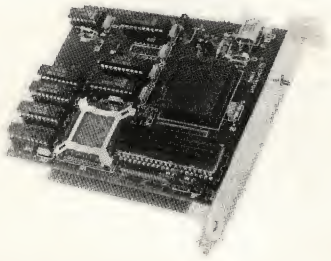

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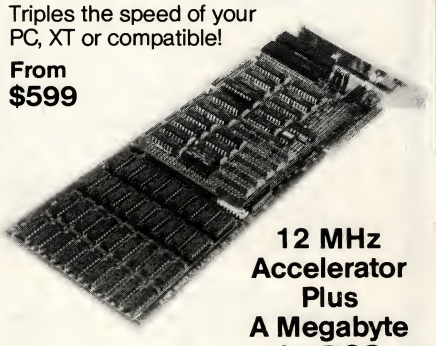

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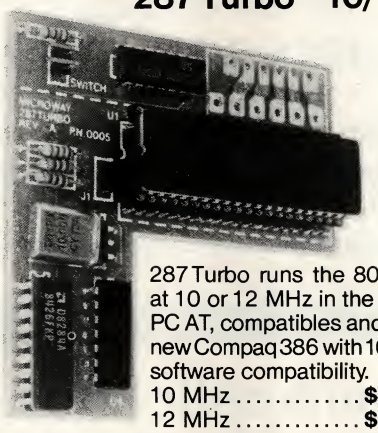

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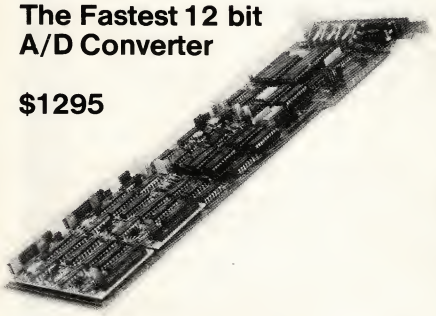

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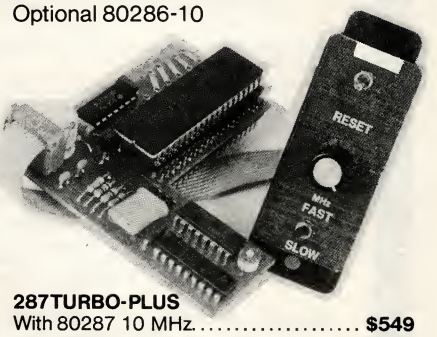

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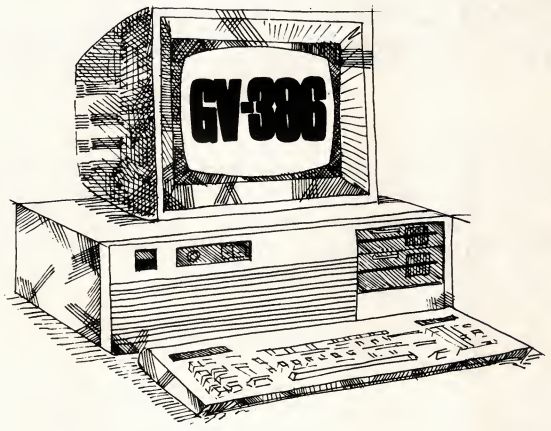

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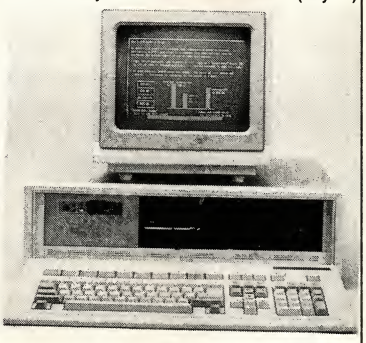

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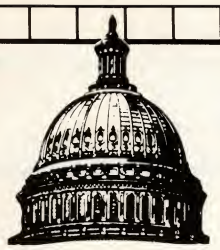

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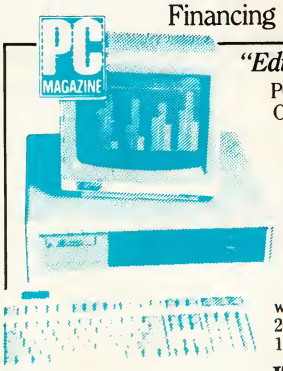

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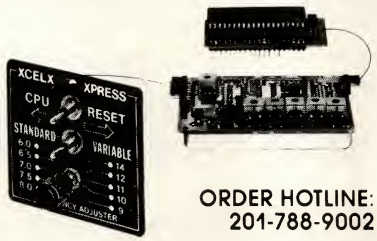

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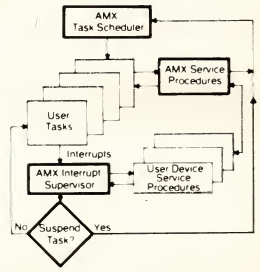

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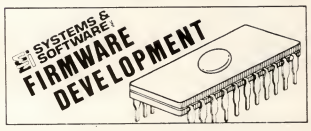

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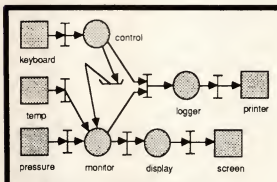

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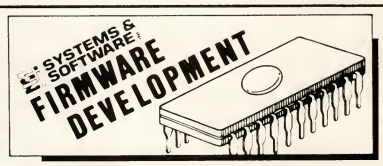

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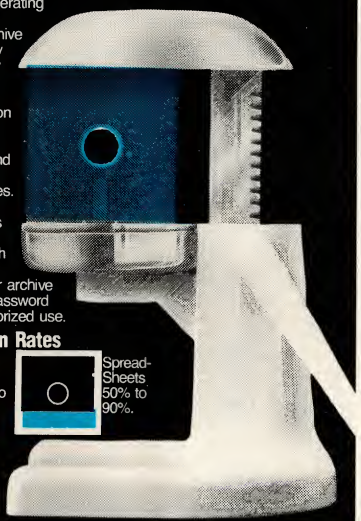

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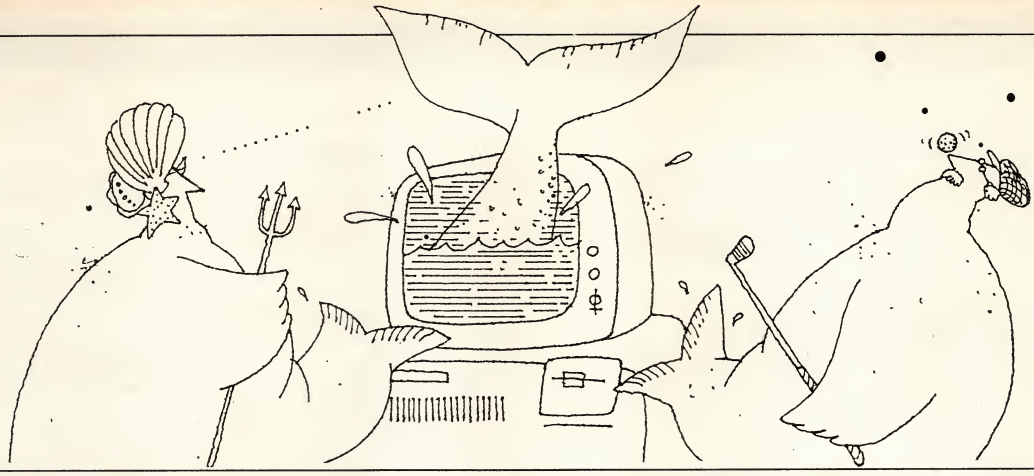

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Reliability in Distributed Software and Database Systems
Williamsburg, VA
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Contact: Edwin C. Foudriat, NASA, Langley Research Center, Information Systems Division, MS 469, Hampton, VA 23665; 804/865-3535

March 17-19
Optical Storage of Documents and Images
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March 22-26
Computer Graphics '87
Philadelphia, PA
Sponsor: National Computer Graphics Association
Contact: NCGA, 2722 Merrilee Drive, Suite 200, Fairfax, VA 22031; 800/225-6422; in Virginia, 703/698-9600

March 23-27
Theory and Practice of Software Development (TAPSOFT '87)
Pisa, Italy
Sponsor: Universitè di Pisa
Contact: Pierpaolo Degano, Dipartimento di Informatica Universitè di Pisa, Corso Italia, 40 I-56100 Pisa, Italy

March 30-April 2
Ninth International Conference on Software Engineering
Monterey, CA
Sponsors: ACM SIGSOFT (Software Engineering) and IEEE-CS
Contact: William E. Riddle, Software Design and Analysis, 1760 Bear Mountain Drive, Boulder, CO 80303; 303/499-4782

March 31-April 3
ANSYS 1987 Conference and Exhibition
Newport Beach, CA
Sponsor: Swanson Analysis Systems, Inc.
Contact: Swanson Analysis Systems, Inc., Johnson Road, P.O. Box 65, Houston, PA 15342-0065; 412/746-3304

March 30-April 3
Robotics and Automation
Raleigh, NC
Sponsor: IEEE-CRA
Contact: Harry Hayman, 738 Whitaker Terrace, Silver Spring, MD 20901; 301/434-1990

APRIL

April 1-3
Database Systems for Office Automation, Engineering, and Scientific Applications
Darmstadt, West Germany
Sponsor: Gesellschaft für Informatik
Contact: H.-J. Schek, Technische Hochschule Darmstadt, Fachgebiet Datenverwaltungs-systeme I, Fachbereich Informatik, Alexanderstraβe 24, D-6100 Darmstadt, West Germany

April 5-9
CHI + GI '87
Toronto, Ontario, Canada
Sponsor: ACM
Contact: Wendy Walker, CHI + GI '87, Computer Systems Research Institute, University of Toronto, 2002-10 Kings College Road, Toronto, Ontario, Canada M5S 1A4; 416/978-5184

April 8-10
Mathematical Foundations of Programming Semantics
New Orleans, LA
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April 9-10
Advanced SPSS/PC+
Austin, TX
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April 9-10
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Atlanta, GA
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April 21-24
PERSCOMP '87
Sofia, Bulgaria
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AI '87
Long Beach, CA
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Contact: Jim Hay, Show Manager AI '87, TCM, 331 W. Wesley Street, Wheaton, IL 60187; 312/668-8100

April 27-29
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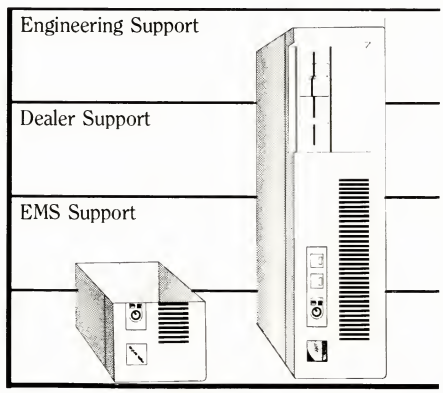

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2 Serial Ports/Parallel Port
Large RT Style Keyboard
Battery Backup Clock Calendar
System Set-up Configuration

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80287 Socket on CPU Card
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EMS Software
High Speed 80Ns 256K DRAM
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Combination Hard Disk/Floppy Controller
2 Serial Ports, 1 Parallel Port
Large RT Style Keyboard
Battery Backup Clock Calendar

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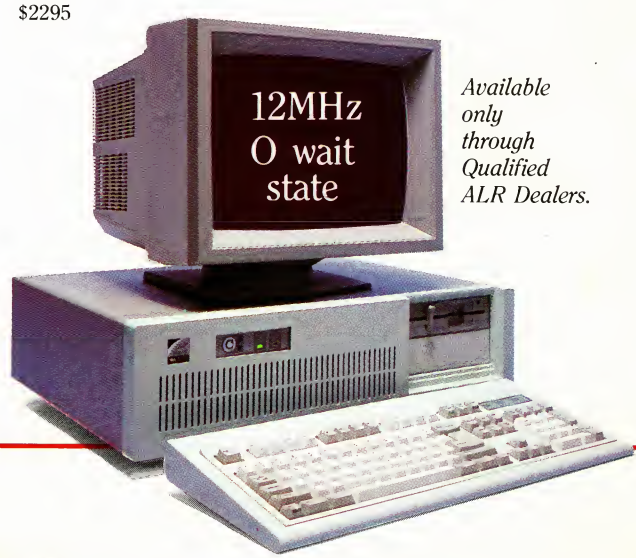

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